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EDITORIAL.

ITEMS AND NOVELTIES.

Useful Effect of the Human Machine as Compared with that of Fire-arms.—It is well known that the useful effect of steam engines varies between three and ten per cent. of the total available work calculable from the transformation of the heat of the fuel into motion. It is also well known that the work done by men and by animals is the result of the combustion of the food which they eat; and that, further, it is to the same transformation of heat into motion, that fire-arms owe their efficiency. But the actual useful effect of the two latter transformations is not as well known. The following details upon this subject, therefore, taken from a paper by M. de Saint-Robert, recently published in the *Revue Scientifique*, are not without interest.

When the human body is at rest, the only effect of the chemical actions going on within it, is simply to produce the heat necessary to maintain its temperature constant at 37° C (98° F.) But if it is in motion, only a portion of the chemical action is transformed into heat, the rest appearing as mechanical work. As in all machines moved by heat, so here; if we divide the work done by the number of units of heat (calories) expended, we shall obtain the mechanical equivalent of heat, which is 425 kilogrammeters (772 foot-pounds.)

In order to obtain the heat thus expended, it would be necessary: 1st, to calculate the heat which would be obtained by burning all the food taken into the body as well as by burning the body itself; 2d, to calculate the heat lost externally, during the whole of life, together with that which would be evolved by the combustion of all matters eliminated from the body during the same time, and by the combustion of the body immediately after its birth; and 3d, to subtract the second of these values from the first.

We have just seen that the useful effect of a steam engine does not exceed on an average, seven per cent. Let us now see what is the actual useful effect of the human machine used as a source of power. The greatest amount of work which a man can do, as is well known, is that which he does in raising his own body in walking up a gentle slope. The measure of the work thus done is of course the product of the weight of his body by the height to which it is raised. The work thus actually stored up, may be utilized by employing the descent of the man to raise a weight equal to his own to the height from which he came. Now actual experiment has proved that, working in this way, a man can perform without over fatigue, a work of 280,000 kilogrammeters (2,000,000 foot-pounds.) On the other hand, the daily food of a working man is, on an average, according to the calculations of Moleschott:*

Albuminoid substances, . . .	130 grams.
Adipose substances, . . .	84 "
Adipogenic, or fat-forming substances, {starch, dextrin, sugar), . .	404 "
Inorganic salts, ...	30 "
Water, ...	2800 "
	3448 grams.

The combustion of these substances would give:†

Albuminoid substances, . . .	650 calories.
Adipose " . . .	762 "
Adipogenic " . . .	1471 " ‡
	2883 calories.

* *Physiologie der Nahrungsmittel*, 2d Ed., p. 223.

† Ranke, *Physiologie*, p. 793.

‡ Calculated on the supposition that the adipogenic substances are reduced to their equivalent in starch. Hence, by reason of the carbon they contain, they are equivalent to 449 grams of sugar.

The mechanical labor equivalent to these 2883 calories is represented by 1,225,275 kilogrammeters, (8,880,000 foot-pounds.) Dividing now the daily work done by the work theoretically possible calculated from the food taken, we obtain for the efficiency of the human machine 0·229; or about 23 per cent. This result accords very closely with that which Helmholtz has given. This eminent physicist estimated the external work of a man to be one-fifth of the available mechanical power contained in his food. The human machine then is greatly superior, so far as effectiveness is concerned, to the steam engine. But it is very much more costly. Indeed, according to the estimate of the work of a man given above, it would be necessary to have eight men to obtain one horse power. Now estimating the cost of coal at ten dollars a ton, and the wages of a man at forty cents, the expense of this amount of power for each day of eight hours, would be about ten cents for the steam engine, and three dollars and twenty cents for the eight men.

Fire-arms, too, belong to the great class of thermic machines. They are employed for the purpose of transforming into motion a portion of the heat produced by the combustion of the powder. The gases which are evolved during the combustion of the charge drive the projectile and the gun in opposite directions, impressing upon them opposite velocities. At the same time, a certain quantity of heat disappears, being transformed into work. The total work accomplished by the powder is equal to the product of the weight of the projectile by the height to which it would rise if projected vertically in a vacuum, plus the product of the weight of the gun, by the height due to its velocity. This latter product, however, being ordinarily very small in relation to the former one, may be neglected. We may measure, therefore, with sufficient accuracy, the effect of the powder by the work done on the projectile. Hence it is obvious that the useful effect of a fire-arm is measured by the ratio between the work actually done, and that which is the equivalent of the quantity of heat set free by the combustion of the charge.

Taking, for example, a rifled cannon, the diameter of the bore of which is 7·5 centimeters, (3 inches), the shell of which weighs about 3·7 kilograms, (8·3 pounds), and the firing charge of which is 0·55 kilogram, (1¼ pounds), it is easy to calculate its effectiveness. Experiment has shown that the velocity of the shell when it leaves the mouth of the cannon is about 400 meters (1300 feet) per second.

The height from which this projectile would have to fall to acquire this velocity, is 8158 meters (26,800 feet). Consequently the work actually done by the powder is equal to 30,185 kilogrammeters (219,000 foot-pounds).

On the other hand, Bunsen and Schischkoff have found by direct experiment, that the heat evolved by the combustion of a kilogram of gunpowder is equal to 619·5 calories. Hence the heat evolved by the above charge of 0·55 kilogram is equal to 340·7 calories. The mechanical work corresponding to this amount of heat is 144,798 kilogrammeters (1,050,000 foot-pounds). Comparing this, which is the possible mechanical work, with the actual work done on the projectile as given above, the ratio is 0·208 for the effectiveness of the cannon; that is to say, about 21 per cent.

Velocity of Magnetization and Demagnetization of Wrought Iron, Cast Iron, and Steel.—The question of the rapidity with which iron acquires and loses its magnetism is an exceedingly important one in all cases where electro-magnets are employed in rapid transmission or in time determinations. We find in the *Revue Industrielle*, the following note upon this subject, communicated to that journal by M. Deprez:—

"In the course of my researches upon electro-magnets and their application to the registering of very rapid phenomena, researches, the first results of which were communicated to the Academy of Sciences, I have been led to investigate the question of the influence of the iron itself upon the duration of the magnetization and demagnetization. For this purpose, I have used a registering apparatus, in which the pieces of iron constituting the electro-magnet are removable, while all the other parts, the coils, armature, style, etc., remain the same; so that the only change in the results obtained must be due to the influence of the metal which forms the electro-magnet. In order to measure the time of the magnetization and demagnetization, I have employed the electric chronograph, which was described in my earlier communication. The metallic portion of the electro-magnets, which I place successively within the magnetizing helices, consists of two cores, two millimeters in diameter and thirteen millimeters long. The coils through which the current passes, contain 14 meters of wire, one-fifth of a millimeter in diameter. The battery used was a single Bunsen element, as modified by M. Dulaurier.

Finally, the varieties of iron examined were the ordinary wrought iron of commerce, a specially soft telegraphic iron, malleable cast iron, gray cast iron, and cast steel drawn into bars and tempered.

The results which have been obtained in this investigation were entirely unexpected. They prove that the soft iron, the ordinary wrought iron, the malleable cast iron, and even the tempered steel require very nearly the same period of time for their magnetization and demagnetization; namely,

For the demagnetization, ...	0·00025 second.
For the magnetization, (approximate), .	0·00150 "

The gray cast iron gave the best result of all, the time required for its magnetization, being only about one-thousandth of a second. This metal, therefore, is altogether the best to be used when the object is to attain the greatest possible rapidity in the transmission of signals.

In general, then, these facts prove that with the registering apparatus actually employed, perfectly distinct signals can be obtained at intervals of one three-hundred-and-fiftieth of a second, whatever the kind of iron used in the electro-magnets; and that if the cores of the magnet are made of gray cast iron, the interval between successive signals may be reduced to one five-hundredth of a second. It is necessary to say, however, that I do not refer to signals succeeding each other regularly at intervals of 1-350th or 1-500th of a second; in this case the number of signals which could be transmitted would considerably exceed 350 to 500 per second.

I am inclined to believe that this superiority of cast iron depends upon its molecular structure and has no relation to the quantity of carbon which it contains. Hence I purpose examining wrought iron which has been cast and not hammered, and which, I am confident, will surpass in the rapidity of its action all the irons which I have hitherto examined. It is my intention to give before long some details of my experiments on this subject, and some facts concerning the application of my registering apparatus as an electric chronograph for artillery purposes.

It is important to observe that the absolute time required for magnetization and demagnetization which is given above, does not include the time occupied by the style in making its record. It is by adding this time to that required for the magnet to act that the values 1-350th and 1-500th of a second are obtained. This therefore repre-

sents the total duration of a signal, and includes the demagnetization, the time of fall of the style, the magnetization and finally the return of the style to its primitive position. Moreover these numbers are correct only when but a single cell of the battery is employed, the number of signals transmitted per second, increasing with the intensity of the current."

Magnetization of the Rails on Railways.—M. Herzog, engineer-in-chief of the Hungarian railways, after a series of experiments on the magnetization of rails, gives the following as his conclusions:

1. The rails which are taken up and replaced after several years of service, do not by any means deserve to be called powerful magnets, since a steel rail about 40 square centimeters, (6·16 square inches) in cross section, manifests immediately upon its removal, a magnetic force scarcely equal to that of a saturated steel plate half a square centimeter in section. It is to be observed, however, that steel rails possess a much higher magnetic power than rails of ordinary iron.

2. Rails in place are also magnetic, and this whether the fish-plates are removed or not, provided there is between them the space usually allowed for expansion in all well-constructed lines.

3. Rails removed from the roadbed and piled up show traces of magnetism even after many months. This persistance of the effect is more pronounced in Bessemer rails than in those of ordinary iron.

4. A rail thrown out of use in consequence of fracture, shows on the two surfaces of separation opposite polarities. This is precisely the same fact which is observed when a magnetized bar is fractured; there are as many magnets as there are pieces.

5. Entirely new rails, which have never been in actual service, acquire feeble magnetic properties when they are arranged in piles and placed parallel to the magnetic meridian. This remark applies more particularly to steel rails, which, under the influence of a few blows with the hammer, are converted into permanent magnets.

This last observation leads M. Herzog to the conclusion that all these phenomena are attributable to terrestrial magnetism, and are only a confirmation of the following theoretical principles:

a. A bar of iron placed in the direction of the dipping needle, becomes a magnet under the influence of terrestrial magnetism. The same is true for any bar of iron placed in the magnetic meridian; its magnetic intensity diminishes in proportion, as the angle between the

two increases. This fact is very noticeable with rails laid on a curve; the more they vary from a north and south direction, the less intense is the magnetism at their ends.

b. A bar of iron exposed for a long time to the influence of terrestrial magnetism, becomes a permanent magnet.

c. For steel rails, the effect is more prompt, and more intense than for iron ones. Under the action of the hammer, they become permanent magnets. This latter effect is produced daily upon rails in use, since they are submitted at the same time to the combined influence of terrestrial magnetism and the jars produced by the passage of trains.

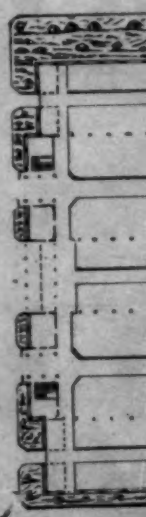
A Locomotive on Feet.—The well-known French engineer, M. Tresca, has recently called the attention of the Academy of Sciences to a very curious experimental locomotive now on trial on the Eastern Railway. A small model, worked with compressed air, is on exhibition in Paris. This locomotive has no wheels, but in place thereof it has legs. It does not roll then on the rails, but it walks, runs and gallops. Suppose an ordinary locomotive with straight shafts, terminated by large circular feet. Three of its legs are in front and three behind. The motor cylinders, in place of revolving the wheels, cause these large treadles to rise and fall. The treadles placed on the side are brought special action when the machine trots, those in the middle when it gallops. The whole treadle system acts like a horse with three legs, having a gait resembling an amble and a trot at the same time. Nothing can be more surprising to look at. It would almost seem as if there actually was an animal concealed in the machine, whose legs only were visible and sustained the whole. The object of this novel arrangement is said to be to reduce the dead weight of the locomotive itself, and to increase its adherence. With this machine on feet, a grade of one in ten may be ascended very readily. The locomotive being experimented with on the Eastern Railway of France weighs ten tons, and runs at a speed ordinarily of 7 to 8 kilometers (4 to 5 miles) an hour, though it can run as high as 20 kilometers (12·5 miles). This construction of a locomotive is obviously only applicable under very special circumstances. Mountain railways, special local railways, and common roads, are of course best adapted to it. It is the invention of a well-known constructor, M. Fortin Hermann.

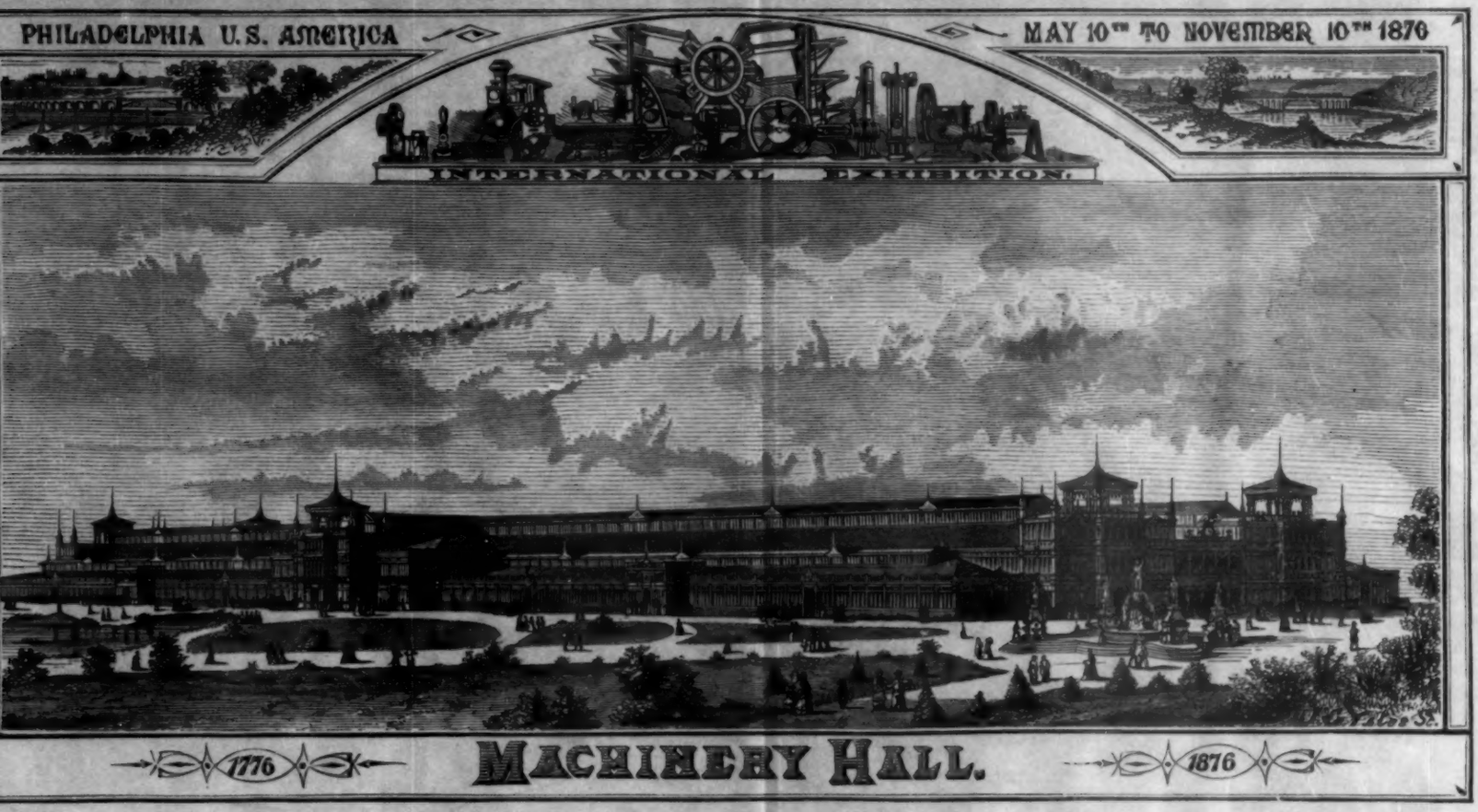
Centennial Exhibition.—We present with this issue of the JOURNAL illustrations of the Machinery Hall, showing a perspective of the complete building, with the ground plan and two sections of the frame-work, one across the main building looking towards the transept, showing half the width, and the other through the annex, showing the water tank. By reference to the situation plan in the April number and the bird's eye view of the Buildings and Grounds in the last number it will be seen that this structure is located west of the intersection of Belmont and Elm Avenues; the distance from the west front of the Main Exhibition Building, being 542 feet from the north side of Elm Avenue, 274 feet. The north front of the Building will be upon the same line as that of the Main Exhibition Building, thus presenting a frontage of 3,824 feet from the east to the west ends of the Exhibition Buildings upon the principal avenue within the grounds.

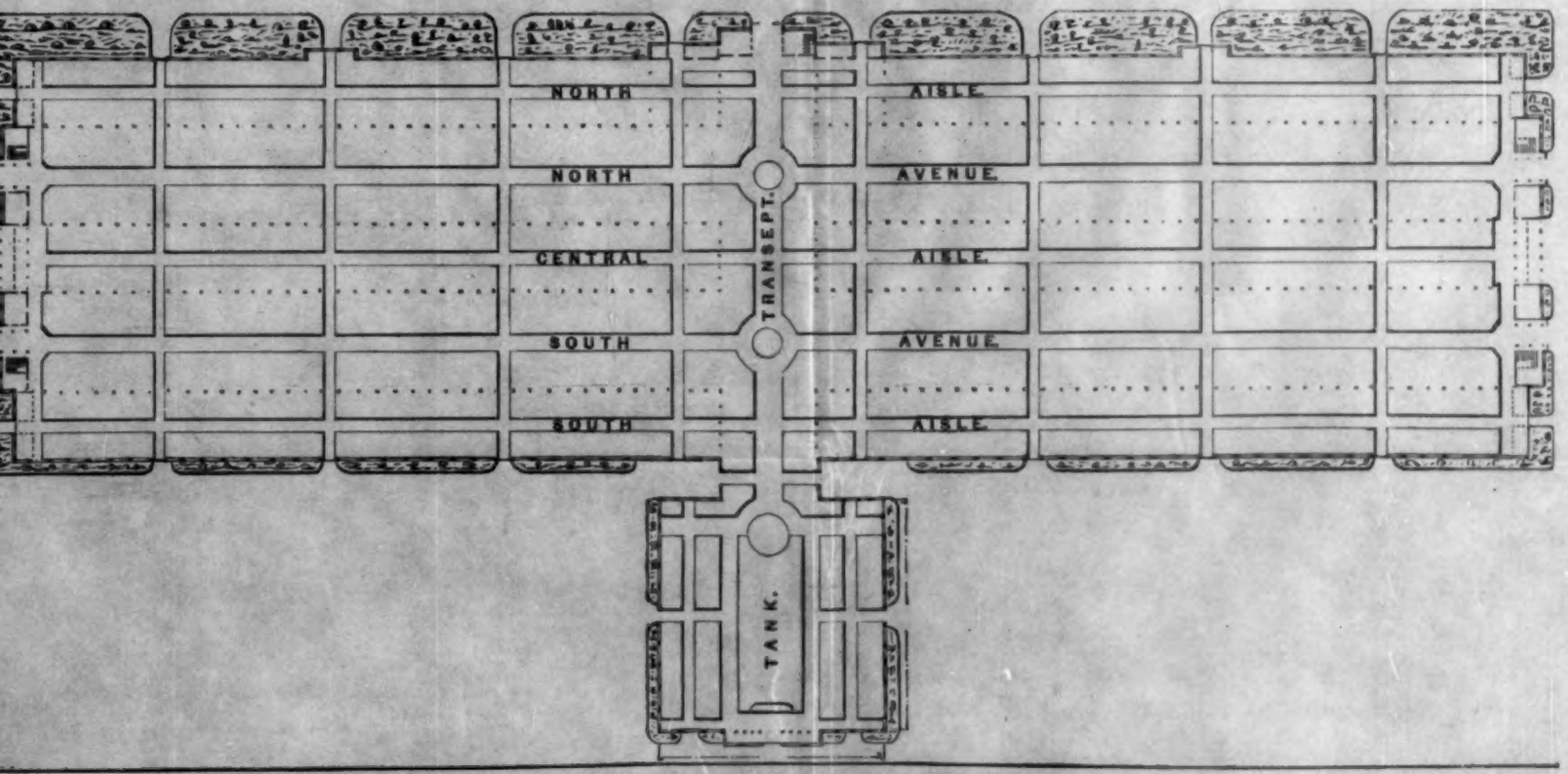
The Building consists of the Main Hall, 360 feet wide by 1,402 feet long, and an annex on the south side of 208 feet by 210 feet. The entire area covered by the Main Hall and annex is 558,440 square feet, or 12·82 acres. Including the upper floors the building provides 14 acres of floor space.

The principal portion is one story in height, showing the main cornice upon the outside at 40 feet from the ground, the interior height to the top of the ventilators in the avenues being 70 feet, and in the aisles 40 feet. To break the long lines upon the exterior, projections have been introduced upon the four sides, and the main entrances finished with facades, extending to 78 feet in height. The east entrance will form the principal approach from street-cars, from the Main Exhibition Building, and from the railroad depot. Along the south side will be placed the boiler houses and such other buildings for special kinds of machinery as may be required. The west entrance affords the most direct communication with George's Hill, which point affords the best view of the entire Exhibition grounds.

The arrangement of the ground plan shows two main avenues 90 feet wide by 1,360 feet long, with a central aisle between and an aisle on either side. Each aisle is 60 feet in width; the two avenues and three aisles making the total width of 360 feet. At the centre of the building is a transept of 90 feet in width, which at the south end is prolonged beyond the Main Hall. This transept, beginning at 36 feet from the Main Hall and extending 208 feet, is flanked on







Ground Plan, Machinery Hall.

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NORTH
CENTRAL
SOUTH
SOUTH

International Exhibition.
Philadelphia. 1876.

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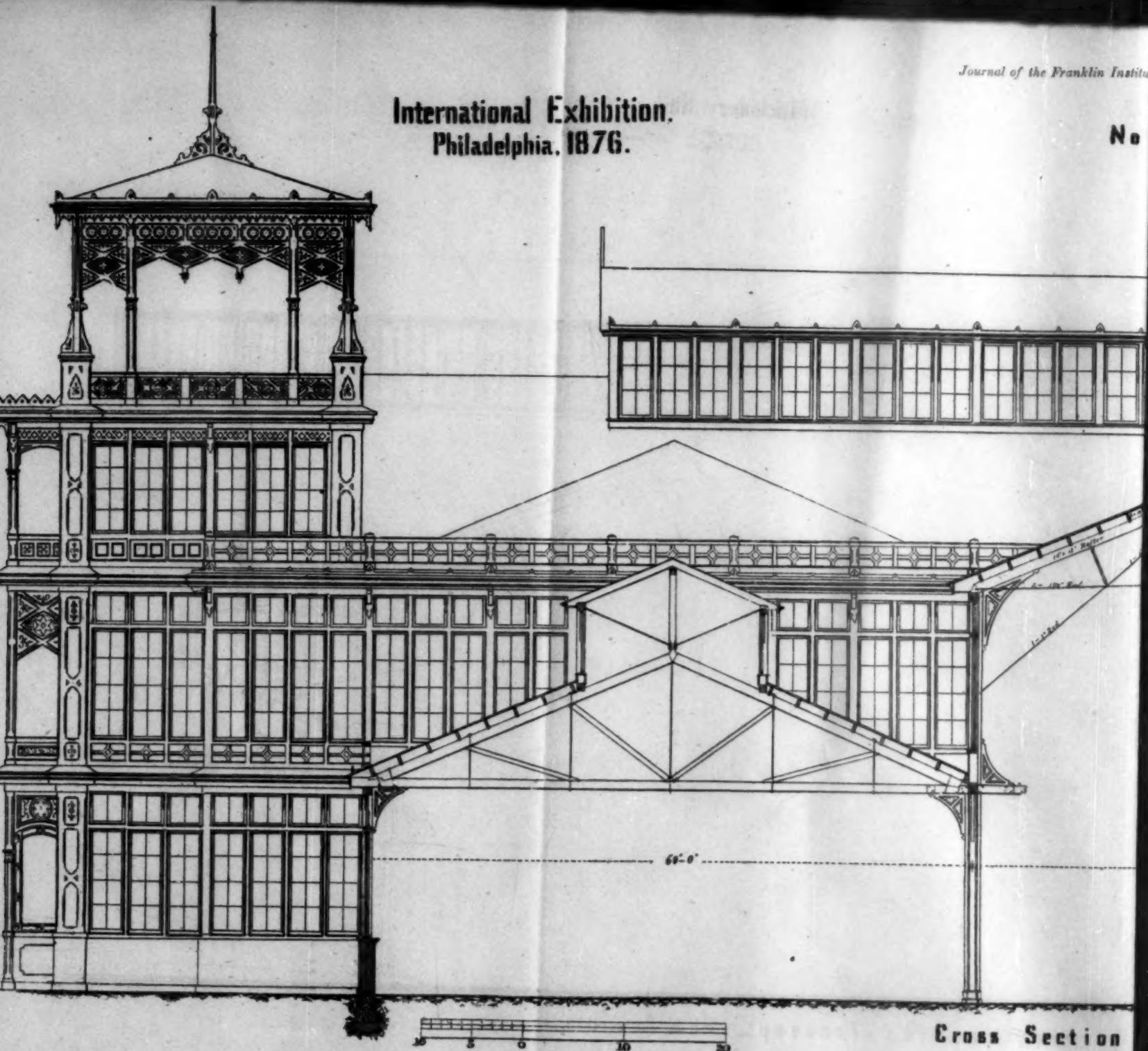

Cross Section

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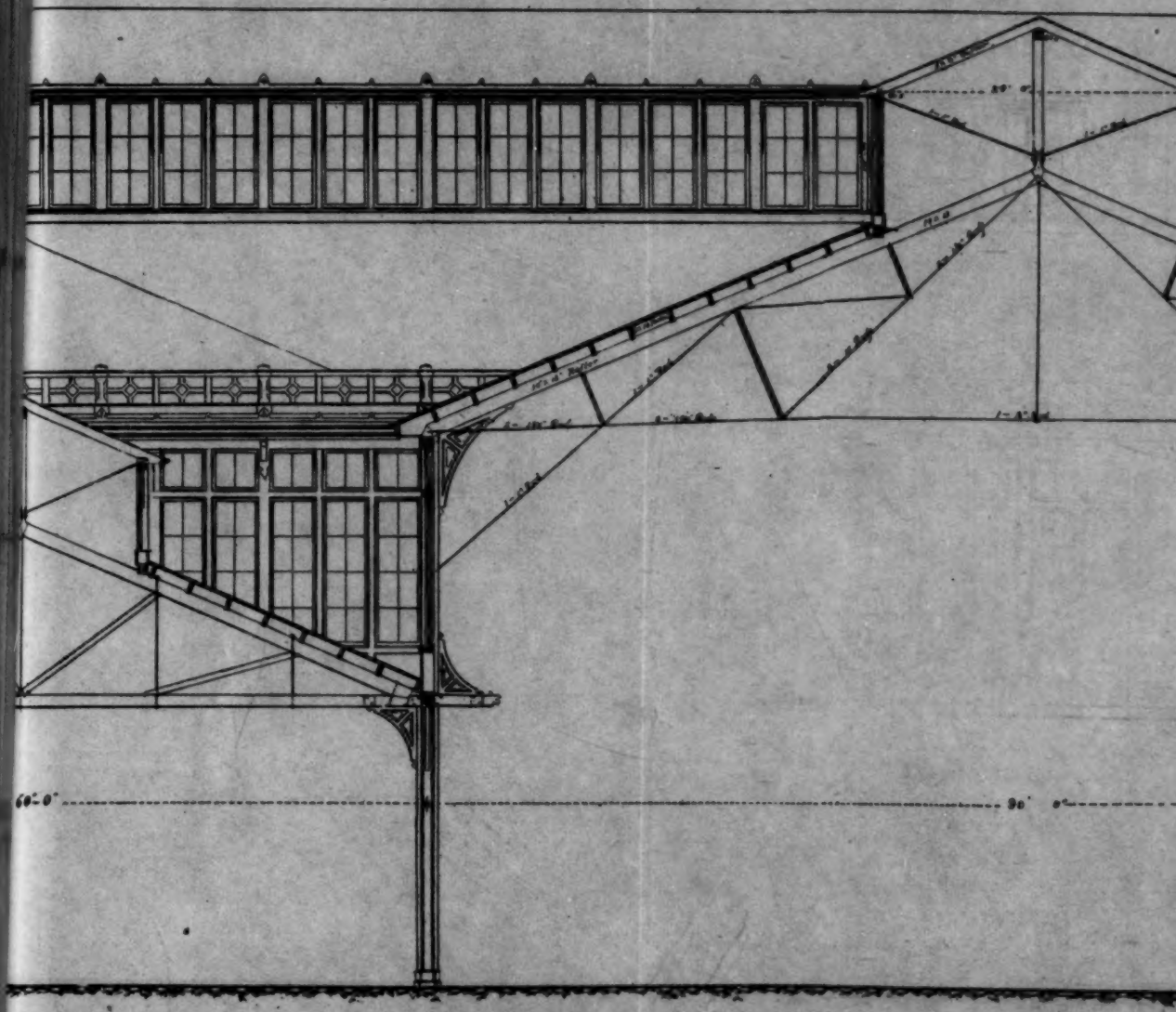

Cross Section Looking towards Transept.

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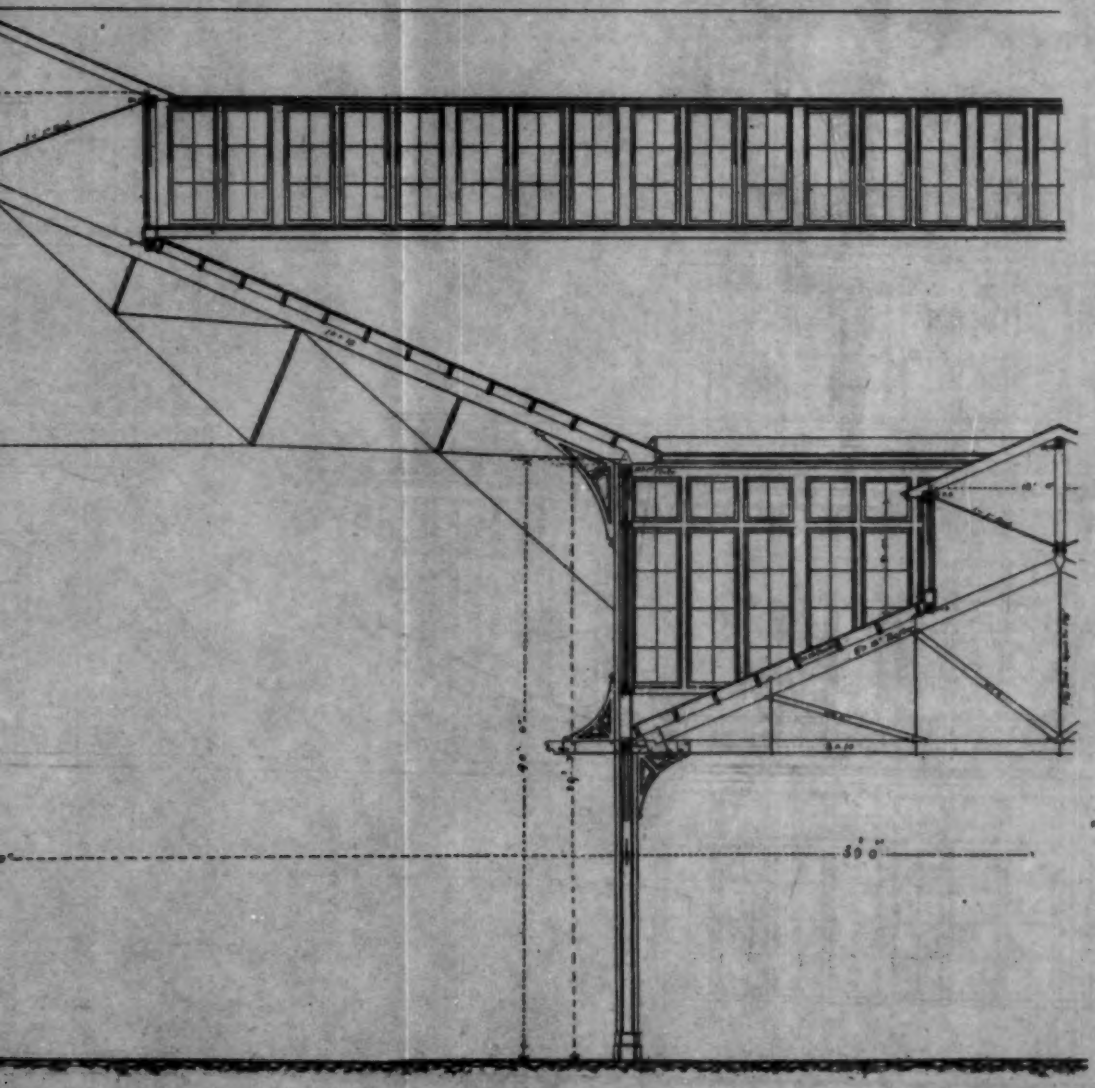
Machinery Hall.



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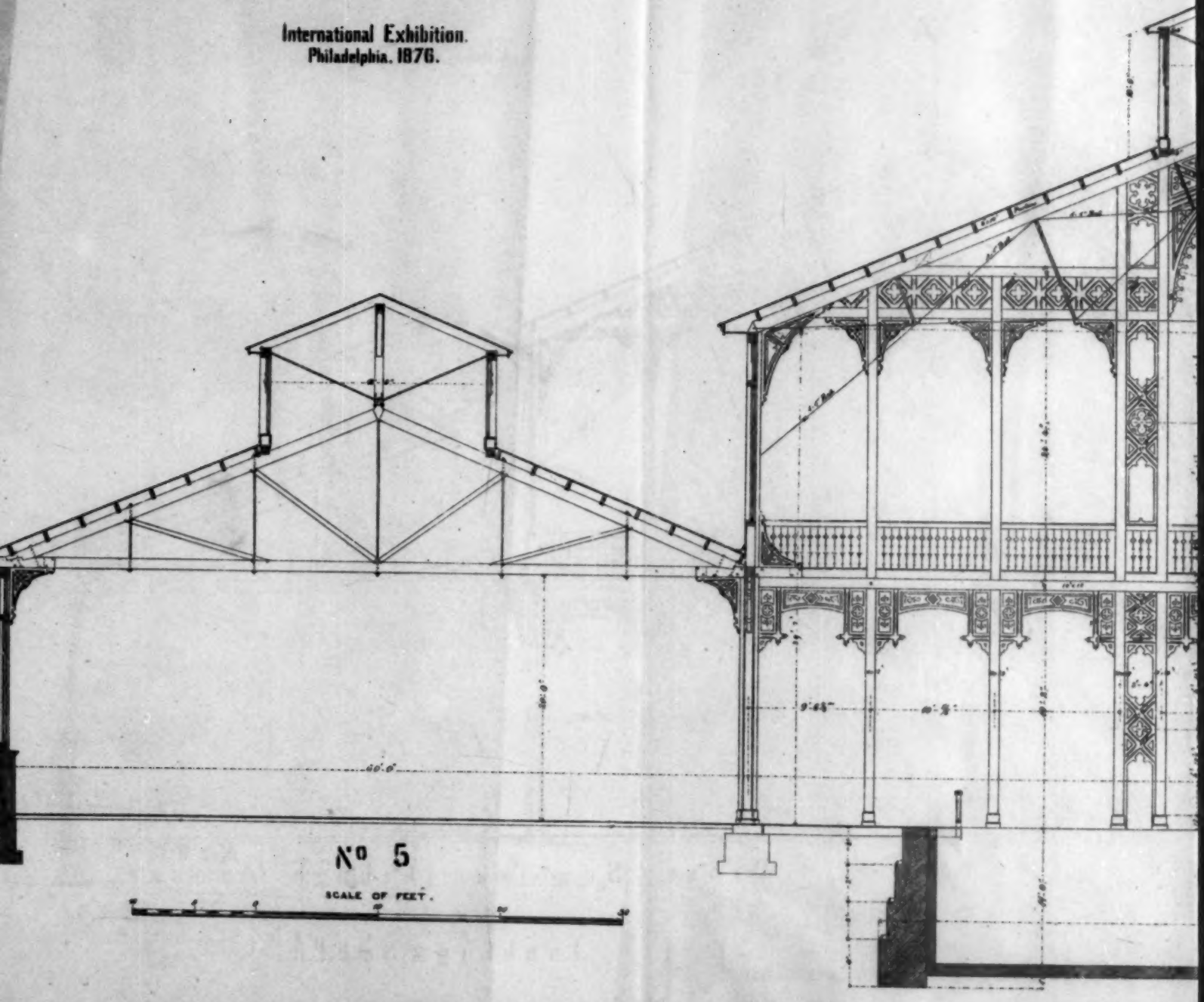
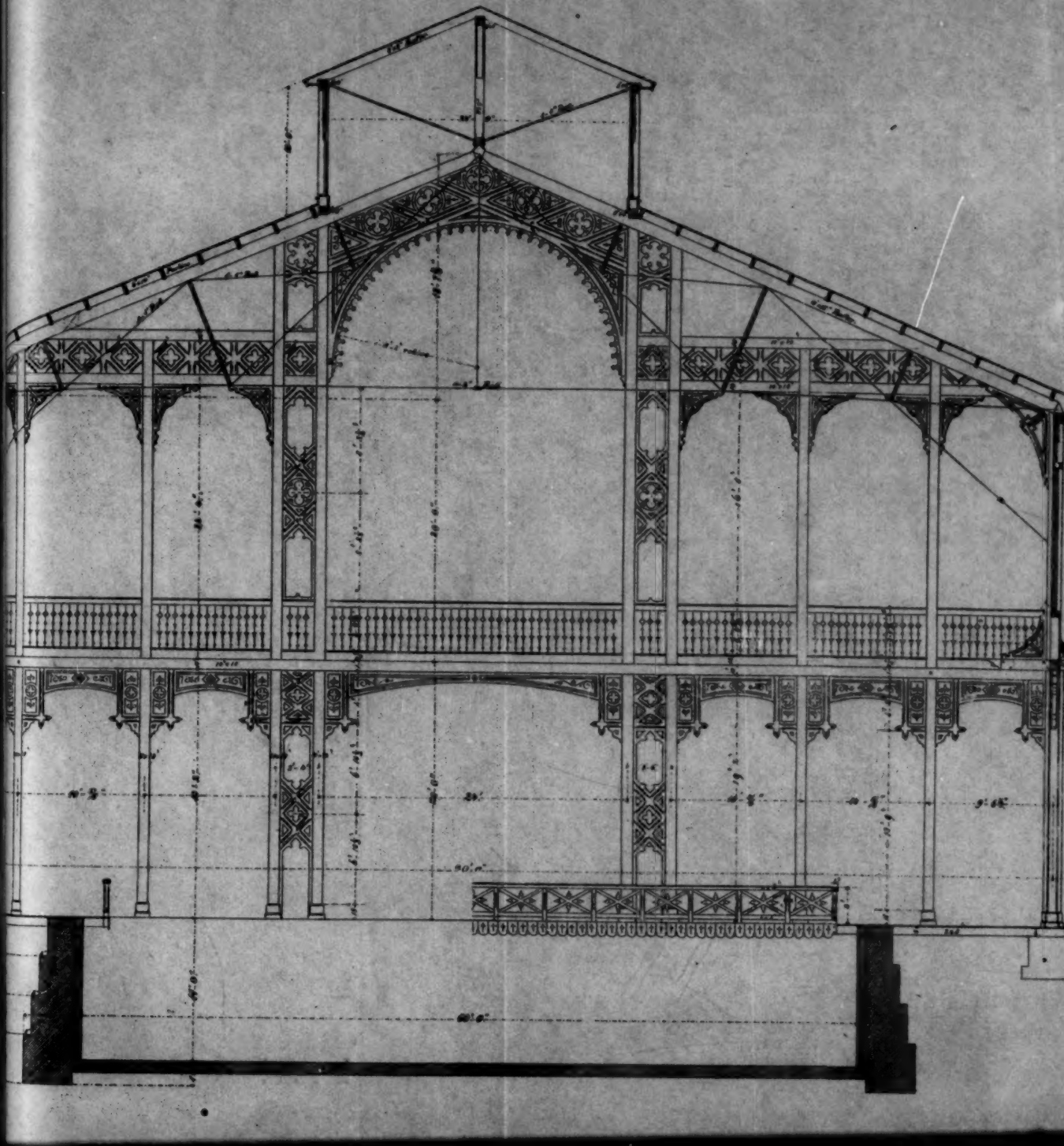
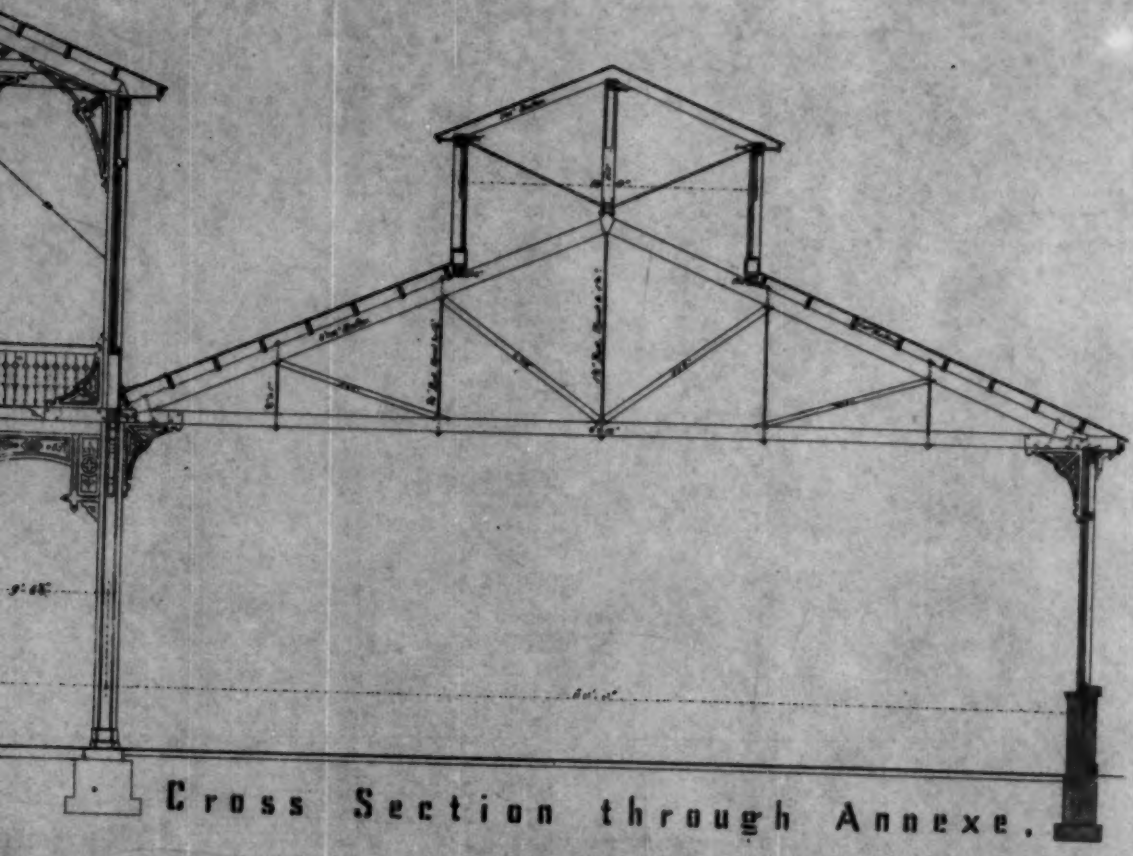


N° 5

SCALE OF FEET.

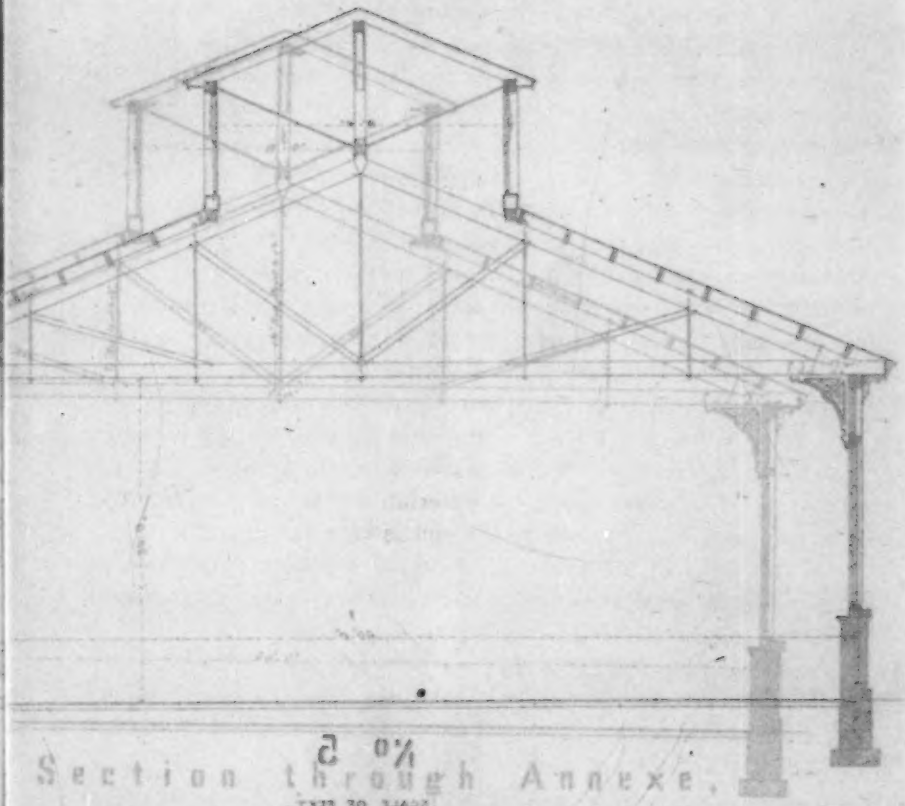


Machinery Hall.



Cross Section through Annexe.

Looking South.



Section through Annexe,

Looking South.

either side by aisles of 60 feet in width, and forms the annex for hydraulic machines. The promenades in the avenues are 15 feet in width; in the transept 25 feet, and in the aisles 10 feet. All other walks extending across the building are 10 feet in width, and lead at either end to exit doors.

The foundations consist of piers of masonry. The superstructure consists of solid timber columns supporting roof trusses, constructed with straight wooden principals and wrought iron ties and struts. As a general rule the columns are placed lengthwise of the building at the uniform distance apart of 16 feet. The columns are 40 feet high to the heel block of the 90 feet span roof trusses over the avenues, and they support the heel of the 60 feet spans over the aisles, at the height of 20 feet. The outer walls are built of masonry to a height of 5 feet, and above that are composed of glazed sash placed between the columns. Portions of the sash are movable for ventilation. Louvre ventilators are introduced in continuous lengths over both the avenues and the aisles. The building is lit entirely by side light, and stands lengthwise nearly east and west.

The facilities for the most complete system of shafting, are very superior. Eight main lines may be introduced, extending almost the entire length of the structure, and counter-shafts introduced into the aisles at any point. The hangers will be attached either to the wooden horizontal ties of the 60 feet span roof trusses, or to brackets especially designed for the purpose, projecting from the columns, in either case at the height of 20 feet from the floor.

The annex for hydraulic machines contains a tank 60 feet by 160 feet, depth of water of 10 feet. In connection with this it is expected that hydraulic machinery will be exhibited in full operation. At the south end of this tank will be a waterfall 35 feet high by 40 feet wide, supplied from the tank by the pumps upon exhibition.

On either side of this tank will be deep trenches connected with it, from which the pumps may take their supply of water, by means of pipes passing directly down through the floor.

Discharge pipes leading to the waterfall will also be placed under the floor, so that the pumps may make easy connection with them; but those pumps nearest the tank may have pipes overhead discharging directly in the tank, if desired.

A contract has been entered into with Mr. Geo. H. Corliss, of Providence, R. I., to furnish the steam power for the Main Hall. The engines

will be placed at the intersection of the transept with the south avenue, and will be of the following general description: One pair of beam engines, with cylinders of 46 inches diameter, 10 feet stroke, making 35 revolutions per minute and capable of being worked up to 2000 horse-power, if required.

The main shaft of these engines will run north and south, and the principal lines of shafting running east and west will be driven from it by bevel gear wheels.

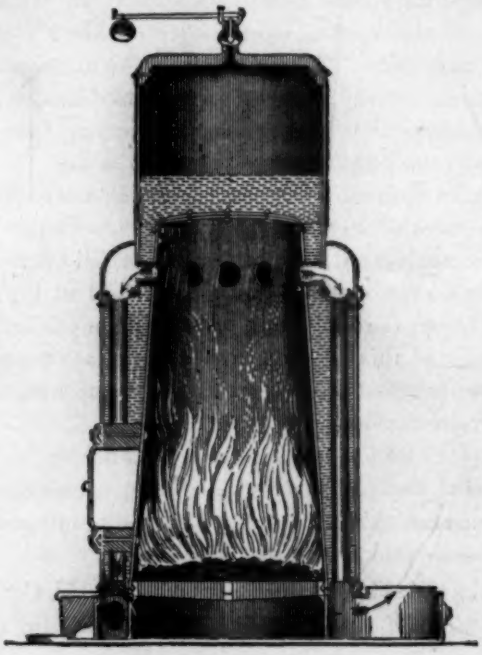
The steam will be furnished from 20 upright Corliss boilers, placed in a house at the east side of the annex.

Another engine will probably be located in the annex to drive such hydraulic machines as require belt power.

The water wheels will be located at the south end of the annex, in the immediate vicinity of the waterfall, from the head of which they will take their supply of water.

The progress on this as on the Main Building, Art Building and Horticultural Hall for the month is very encouraging. K.

The Shapley Portable Steam Engine.—One of these engines of five horse-power was loaned by Messrs. Henry Snyder & Co., and



used at the meeting of the Institute in June to drive the Gramme Magneto-Electric Machine. A similar one of eight horse-power was placed in competition at the late Exhibition, and was the only one of this class that was submitted to a thorough test, and the extract from the Report of the Judges, given below, shows its performance, which is worthy of attention.

The principal peculiarity is in the boiler, the construction of which is shown in the accompanying cut.

The engine is of the plain three port slide valve pattern, and stands upright on the base plate which supports the boiler. The exhaust steam passes through the feed-water heater on its way to the chimney. The whole is mounted on small wheels.

The following is taken from the Report of the Judges:

Total area of heating surface in square feet,	69·5
Area of grate surface " " "	3·14
Steam (pressure) per square inch, in pounds,	67
Temperature of feed-water,	177°
Diameter of cylinder,	6 in.
Stroke of piston,	10 "
Indicated horse-power,	11·35
Horse-power by Dynamometer,	10·40
Percentage of loss by friction,	·09

K.

Bibliographical Notices.

THE CHEMISTRY OF LIGHT AND PHOTOGRAPHY. By DR. HERMANN VOGEL, *Professor in the Royal Industrial Academy of Berlin.* International Scientific Series, Vol xiv. Small 8vo., pp. xii, 288. New York, 1875: D. Appleton & Co. In more than one respect this book is a stain upon the excellent International Scientific Series, now in course of publication. So far as the labor of the distinguished author himself is concerned, the book is in every way worthy of the position it occupies in the Series. It is clearly and lucidly written; the subject it attempts to treat is well embraced within its pages; and the matter is so well digested, and at the same

time so comprehensive, that not only will the general public, for whose instruction the Series was primarily designed, be profited by an examination of the book, but also the professional photographer cannot fail to be well repaid for an attentive perusal of its pages. Moreover, the work of the publisher, so far as the general make-up of the book is concerned, is well done, and in keeping with the other volumes of the Series. But the work of the translator is simply execrable. The rendering of the German words into English is in numberless cases incorrectly and carelessly done; the chemical and technical words are, in general, wrongly translated, and in some cases, so distorted that even a chemist would not recognize what was meant; in some places the author is made to say directly the reverse of what he intended to say; and in several instances the translator has not only failed to give us the author's meaning, but he has not even made good sense, much less good English, of what he has given us. In short, the translation is evidently job-work, cheaply done, and without the supervising eye of any competent person. And if the American publishers of the International Scientific Series intend to give us such translations as this for the remaining numbers of the Series, which are announced to appear from foreign authors, we can assure them that they will find it difficult to maintain the high character of the enterprise, which they have thus far so well carried out. But that what we have written may not appear to be all assertion, we will cite a few examples of the errors of translation referred to above. On page 19 the translator says:

"By employing *Iodide of Bromium*, and Voigtlander's lens, the process of exposure was made a matter of seconds."

Iodide of Bromium not being a common chemical, and not being mentioned in the chemical dictionaries, it became necessary to refer to the author's own words, to see whether he had really made use of such a term. By consulting a German copy of the book we find that the author, in his historical sketch of Photography, was saying that at first only iodine was used to render the daguerreotype plates sensitive to light, and that such a plate needed exposure to the light for twenty minutes. Soon it was found that bromine used along with the iodine shortened the exposure to one or two minutes, and finally the invention of a new lens and the use of Brom-iodine, (Bromiod), that is Bromine and Iodine together, as was entirely evident from the context, shortened the exposure to seconds.

Again on page 107, under the head of Operation of Light on the Elements the translator gives us the following:

"The chemist understands by the term elements, simple insoluble bodies. * * * * * The chemical elements are the well known metals, also sulphur, phosphorus, chlorine, (a greenish strong-smelling gas developed from chloride of lime); further the less known substance, bromine, (a brown unpleasantly smelling substance of a fluid nature);

lastly iodine, (a black substance also of a fluid nature and used for friction). All these elements unite together and produce bodies with new properties. * * * * * Sulphur unites with oxygen and produces the pungent strong-smelling sulphuric acid."

That the distinguished author of the book, Dr. Vogel, would not make so many mistakes in the space of half a page seems more than probable, and so we consult our German copy again and find that what he really did say is: "The chemist understands by the term elements, simple undecomposable bodies. * * * * * * All the well-known metals are elements, likewise sulphur, phosphorus, chlorine, (the greenish unpleasantly smelling gas which rises from chloride of lime; further the less known substance bromine, a brown stinking fluid), and the black volatile iodine which is used in embrocations. All these elements combine one with another and produce bodies with entirely new properties. * * * * * Sulphur combines with oxygen and produces the pungent, strong-smelling sulphurous acid." All, even those not chemists, will recognize the magnitude of the mistake in the last sentence when we say that sulphurous acid is the suffocating gas which arises when a sulphur match is burned, and that sulphuric acid is the quiet, heavy liquid commonly known as oil of vitriol.

Again, on page 111, when speaking of the decomposition of chloride of silver by the action of light, the translator makes the author say:

"The chloride is liberated and disappears partly as a greenish gas which, from its abundance as well as its odor, can be perceived to be chloride of silver."

What the author did say was: "The chlorine becomes free and disappears partially, as a greenish gas, which in case the amount of chloride of silver is large may be recognized even by the smell."

Again in the following page the translator says:

"We have previously seen in treating of the practical part of photography that plates of iodide of silver and of chloride of silver are exposed in the camera."

But the author says: "We have seen above, in speaking of the practical part of photography that it is not chloride of silver but iodide of silver plates which are exposed to the action of light in the camera obscura."

Still further, in speaking of the use of photography in the determination of the sun's distance by the Transit of Venus method, the translator says:

"But Venus is not visible at the moment when it is placed before the sun's disk."

Whereas, on the contrary, the author says: "On such an occasion, (that is when Venus is between the sun and the earth) Venus is only visible when it is directly before the sun's disk."

Again, on page 222, the translator gives us the following curious chemical transformation:

"The last combination, chromic acid (the author had been enumerating the combinations of chromium with oxygen), is the best known of all; on adding to it sulphuric acid it changes to chromate of potash and crystallizes into red needles which easily lose part of its oxygen."

But the author is not so faulty in his chemistry as this. His statement is: "The latter combination, chromic acid, is the best known of all; it separates, on the addition of sulphuric acid to chromate of potash, and crystallizes in red needles which very easily lose part of their oxygen."

On the following page too the translator makes use of the following singular sentence:

"Chromic acid is of special interest in the object that engages it because both it and its salts are sensitive to light."

But the author says: "In reference to our subject (*i.e.*, photography) chromic acid is of especial interest, inasmuch as both it and its salts are sensitive to light."

And thus we might go on and cite numerous errors of smaller importance, but perhaps we have given enough to show that the translation is worthless. And the proof-reading is not much better. We have purposely omitted, in what we have given above, citing any error which by any means might be attributed to the proof-reader, but it was not for want of material. There are scarce a dozen pages together throughout the book which are not disfigured by errors that a careful proof-reader would detect. In short, the book in its present form is a disgrace to the publishers who have sent it out, and a decent regard for their own reputation and the rights of the public would seem to demand that they should recall the present edition and issue another after the book shall have passed under the eye of some competent person.

D.

Franklin Institute.

HALL OF THE INSTITUTE, May 19th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock, P.M., Vice-President Charles S. Close in the chair.

There were 125 members present.

The minutes of the stated meeting for April were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at their meeting held on the 12th instant they had, in accordance with the recommendation of the Committee on Science and the Arts, awarded the Scott Legacy Medal and Premium to Thomas J. Rorer, for the "Improved Union Belting," patented by Clark & Flemmer; and the Elliott Cresson Gold Medal to Powers & Weightman, for their manufacture of Citric Acid, and the cheaper alkaloids of Cinchona Bark. Also that there were ten persons elected members of the Institute, and the following donations made to the Library.

Pennsylvania Archives. Second series. Published under direction of Matthew S. Quay, Secretary of the Commonwealth. Edited by John B. Linn and Wm. H. Egle, M.D. Vol. I. Harrisburg, 1874. From the Secretary of the Commonwealth.

The Use of the Steam Engine Indicator; or, Practical Science for Practical Men. By Edward Lyman, C.E., 1874. From the Author.

Statistical Report on the Sickness and Mortality in the Army of the United States. From the Surgeon General U. S. A.

Meteorological Register for Twelve Years, from 1831 to 1842 inclusive. From the Surgeon General U. S. A.

Circular No. 1. Report on Epidemic Cholera and Yellow Fever in the Army of the United States during the year 1867. From the Surgeon General U. S. A.

Statistical Report on the Sickness and Mortality in the Army of the United States, 1860. From the Surgeon General U. S. A.

Statistical Report on the Sickness and Mortality in the Army of the United States. Washington, 1856. From the Surgeon General U. S. A.

Catalogue of the Library of the Surgeon General's Office, U. S A. Washington, 1873. From the Surgeon General U. S. A.

Catalogue of the Medical Section of the United States Army Medical Museum. Washington, 1867. From the Surgeon General U. S. A.

Catalogue of the Surgical Section of the United States Army Medical Museum. Washington, 1866. From the Surgeon General U. S. A.

The Secretary reported that the Committee on Science and the Arts have changed the day of holding the stated meetings, from the third Monday, to the first Wednesday of each month.

The Committee on Plans for the alteration of the Institute Building reported progress.

The Secretary presented his report on Mechanical Novelties, etc., embracing a new Grate-bar Cleaner, the invention of Wm. M. Perrins; a Pocket-book Holder, the invention of Geo. S. Knapp, of Chicago; a Rotary Pressure Blower, the invention of Thos. S. Disston; Merriman's Waterproof Life-Saving Dress, being a duplicate of the one used by Boyton, in his recent passage of the English Channel.

A comparison of Gas Microscopes was then made by Mr. D. S. Holman, using his instrument made by Joseph Zentmayer, of this city, and Messrs. Queen & Co., one made by themselves.

Mr. Holman also exhibited and explained a new arrangement of Diaphragm, to be attached to the tube of the objective of Gas Microscopes, consisting of a rotating disk, with several apertures of different sizes to suit different objects, and placed immediately in front of the object and in the focus of the lens.

The Secretary then projected on the screen a number of views showing the progress on the Centennial Buildings, and also views of the Fairmount and Girard Avenue Bridges.

The proposed amendments to the By-Laws, offered at the stated meeting in April, and postponed to this meeting, came up for discussion, and on motion of Mr. Hoover, they were laid on the table by a vote of 71 ayes, to 11 nays.

Mr. J. E. Mitchell offered the following resolution, which on being put to a vote, was lost:

Resolved, that postal card notices of the next meeting of the Institute be sent to all members in good standing, and thereafter to all those who shall have attended any of the three stated meetings immediately preceding it, to all the officers and members of standing committees and to such others as may desire to have their names added to the notice list. Provided that no member shall be entitled to such notice when six consecutive stated meetings shall have passed without his having attended any of them.

Mr. J. J. Weaver offered the following resolution, which was adopted by 65 ayes, to 17 nays:

Resolved, that hereafter all members in good standing be notified of the meetings of the Institute, by postal card, stating the nature of the business to be brought before it.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

Civil and Mechanical Engineering.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxix, page 349.]

Explanation of tables 1 *to* 6, *both inclusive, containing the data and results of the experiments made with screws A, B, C, D, E, F, G, and H, to determine their relative economic efficiencies.*

In the following tables, numbered 1 to 6, both inclusive, will be found the data and results of all the experiments made with screws, A, B, C, D, E, F, G, and H, to determine their relative economic efficiencies when applied to the propulsion of steam-launch No. 4. For facility of reference, the lines containing the quantities are numbered and arranged in groups; and the columns containing the data and results for the different speeds of vessel at which the experiments were made are lettered.

These quantities were obtained, for each screw, in the following manner, namely:

On a straight line, taken for a base, all the experimental speeds of the vessel were laid off by scale as abscissæ, and on ordinates erected from these abscissæ, at right angles to the base, were laid off, by scale, the corresponding experimental slips of the screw. A fair curve was then passed through the ends of these ordinates, dividing them as equally as possible. Finally, there were laid off, by scale on the base, abscissæ representing the speeds of vessel given in line 1 of the table; and from these abscissæ right-angled ordinates were erected until they cut the curve, and on them were measured by scale, the distances be-

tween the curve and the base, which distances gave the true slips of the screw, as shown in line 2 of the tables, and corresponding to the speeds of vessel shown in line 1. The speeds in line 1 are given in geographical miles of 6,086 feet per hour, increasing for each column of the tables by one-half a geographical mile per hour, commencing in column *a* with 5·0 geographical miles per hour, and ending in column *h* with 8·5 geographical miles. The slip of the screw is expressed in per centum of its speed; the latter being measured by the product of its pitch and of the number of its revolutions made in a given time. The speed of the vessel in the same terms being deducted from the speed of the screw thus obtained, the remainder, expressed in per centum of the latter, is the quantity on line 2. In screws G and H, having expanding pitches in the direction of their axes, the mean pitch is used in all calculations.

From the quantities on lines 1 and 2, that on line 5 is calculated in the following manner:

Let—

A = speed of vessel in feet per hour, (line 1).
B = slip of the screw in per centum of its speed, (line 2).
C = pitch of the screw in feet.

Then—

$$\frac{A \div 1 - B}{C \times 1440} = \text{The number of double strokes of engines' piston,}$$

and of revolutions of the screw, made per minute, given on line 5.

The quantities on lines 6 to 12, both inclusive, grouped under the head of "Distribution of the indicated pressure on the pistons," are obtained from the indicator-diagrams in the following manner:

These diagrams were taken as rapidly as possible by expert assistants from each end of each cylinder; and the average mean pressure from all of them for each experiment ascertained. From this mean pressure and the average experimental number of double strokes of engines' pistons made per minute during the experiment, was calculated the gross effective horse-powers developed, during the experiment, by the engines. The distribution of this power, for each experiment, was then determined as follows: taking, for example, the

experiment in table No. 1, column *a*, in which the gross effective horse-powers developed by the engines, (line 13) was 6·6847.

The pressure required to work the engines and shafting, being, by direct experiment, 2 pounds per square inch of piston, (line 7), and constant for all speeds, the power thus absorbed is (line 14) 0·6109 horse.

Deducting from the gross effective power of 6·6847 horses developed by the engines, this power of 0·6109 horse, there remains the net power of 6·0738 horses (line 15) applied to the shaft, of which 7½ per centum, or 0·4555 horse (line 16) is absorbed by the friction of the load.

The power expended in overcoming the cohesive resistance of the water by the screw-blades, calculated in the ratio of the square of the velocity, and for a value of 0·45 pound avoirdupois per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, amounts to 0 3598 horse (line 17).

The powers (0·4555 and 0·3598 horse) absorbed by the friction of the load and expended in overcoming the cohesive resistance of the water by the screw-blades, being deducted from the power (6·0738 horses) applied to the shaft, there remains 5·2585 horse-powers expended in the slip of the screw and in the propulsion of the hull. And as the slip of the screw is 7.82 per centum of its speed (line 2), the power expended in it is $(5{\cdot}2585 \times {\cdot}0782) = 0{\cdot}4112$ horse (line 18), leaving $(5{\cdot}2585 - 0{\cdot}4112) = 4{\cdot}8473$ horses (line 19) expended in the propulsion of the simple hull.

The quantity on line 19 is the same as that on line 4, and from it the thrust of the screw in pounds can easily be calculated.

Let A = the number of horse-powers expended in the propulsion of the simple hull.

B = the speed of the vessel in feet per minute.

Then

$$\frac{A \times 33000}{B} = \text{the thrust of the screw in pounds.}$$

In this manner the quantity on line 3 is calculated from that on line 4 or line 19 for the speeds of vessel in the different columns of the tables.

The quantities on lines 20, 21, 22 and 23 are simply the per centum which the quantities on lines 16, 17, 18 and 19 are respectively of the quantity on line 15.

The quantities on lines 6 to 12, both inclusive, are calculated respectively from the quantities on lines 13 to 19, both inclusive, using the areas of the pistons, and the speed of piston in feet per minute deduced from the quantity on line 5.

During the entire time of each experiment a dynamometer-diagram was taken, and the mean pressure obtained from it and multiplied by the leverage of the instrument is the same as found on line 3. From this pressure the quantity on line 4 is obtained by multiplying it by the speed of the vessel in feet per minute and dividing by 33,000.

The difference between the thrusts of the screws, as given directly by the dynamometer, and indirectly by the indicator, was very small, as will be seen from the fact that their sum by the dynamometer was 22,142, and by the indicator 22,203, the difference of which is only 0·275 per centum of the larger quantity.

After the experimental thrusts of all the screws in all the experiments were ascertained, both directly by the dynamometer and indirectly by the indicator, as above described, for the experimental speeds of the vessel, the latter were laid off by scale on a straight base-line as abscissæ. From these abscissæ right-angled ordinates were erected, on which the corresponding experimental thrusts of the screws were laid off by scale, and a fair curve passed among their ends so as to equally divide them, leaving as many on one side the curve as on the other. Then there were laid off by scale on the base, abscissæ representing the speeds of the vessel given in line 1 of the tables; and from these abscissæ right-angled ordinates were erected until they cut the curve, and on them were measured by scale the distances between the curve and the base, which distances gave the true thrusts of the screw, as shown on line 3 of the tables, and corresponding to the speeds of vessel shown on line 1. These thrusts are expressed in pounds avoirdupois.

Table No. 1, containing the results of the experiments made with screws A, E, and F, all having the same diameter, 4⅕ feet; the same uniform pitch, 5·126 feet; the same fraction of the pitch, 0·5370, and the same quantity and kind of surface, but differing in the number and arrangement of the blades. Screw A has two blades, one directly opposite the other; screw E has four blades, in two pairs, at right angles to each other; and screw F is a Mangin screw, with two pairs of directly opposite blades, one pair immediately behind the other.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	7·82	8·37	8·87	9·40	10·10	11·56	13 33	14·57
3	Thrust of the screw, in pounds, by dynamometer	315·4	368 8	449 9	560·6	707·0	857·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24 3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	107·1247	118·5443	130·0306	141·6905	153·7779	167·4820	182 2959	196·5007
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·8838	25·3212	30·4249	37·3312	46·3393	56·2773	64·1455	70·1567
7	Pressure required to work the engines, *per se*, in pounds per sq. inch of pistons.	2·0000	2·0000	2·0000	2·0000	2 0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·8838	23·3212	28·4249	35·3312	44·3393	54·2773	62 1455	68·1567
9	Pressure absorbed by the friction of the load, in pounds per sq. inch of pistons	1·4913	1·7491	2·1319	2·6498	2·3294	4·0708	4·6609	5·1115
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	1·1771	1·4436	1·7369	2·0508	2·4298	2·8767	3·4118	3·9955
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·3461	1·6838	2·1773	2·8072	3·8974	5·4712	7·2089	8 6078
12	Pressure expended in the propulsion of the vessel, in lbs. per sq. inch of pistons	15·8693	18·4447	22·3789	27·7244	34·6867	41·8586	46·8639	50·4679
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·6847	8·5592	11·2803	15·0828	20·3195	26·8764	33·3436	39·3083
14	Horse-powers expended in working the engines, *per se*	0·6109	0·6761	0 7416	0·8081	0·8770	0·9551	1·0396	1·1206
15	Net horse-powers applied to the shaft	6·0738	7·8831	10·5387	14·2747	19·4425	25·9213	32·3040	38·1877
16	Horse-powers absorbed by the friction of the load	0·4555	0·5912	0·7904	1·0706	1·4582	1·9441	2·4228	2·8641
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·3598	0·4876	0·6435	0·8326	1·0644	1·3751	1·7732	2·2209
18	Horse-powers expended in the slip of the screw	0·411	0·5695	0·8076	1·1711	1·7069	2·6128	3·7468	4·8231
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	5·92	6·19	6·11	5·83	5·48	5·30	5·49	5·82
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	6·77	7·22	7·66	8·20	8·79	10·08	11·60	12·63
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	79·81	79·09	78·73	78·47	78·23	77·12	7··41	74·05

Table No. 2, containing the results of the experiments made with screw B, having the diameter 4½ feet, the uniform pitch 5·136 feet, two blades directly opposite each other, and the fraction of the pitch 0·2799.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	8·74	9·35	9·99	10·49	11·26	12·83	14·81	16·15
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	999·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	23·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	108·2086	119·8272	131·5226	143·4137	155·7807	169·9850	185·4624	200·2043
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·4559	24·8112	29·8120	36·5831	45·4897	55·2601	62·9728	68·8945
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·4559	22·8112	27·8120	34·5831	43·4897	53·2601	60·9728	66·8945
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4599	1·7108	2·0859	2·5937	3·2617	3·9945	4·5730	5·0171
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·7903	0·9718	1·1681	1·3902	1·6393	1·9546	2·3292	2·8029
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·5047	1·8819	2·4335	3·2093	4·3446	6·0717	8·0057	9·5392
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	15·7110	18·2467	22·1245	27·3899	34·2438	41·2293	46·0649	49·5353
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·6234	8·4776	11·1805	14·9803	20·2075	26·7852	33·3026	39·3308
14	Horse-powers expended in working the engines, *per se*	0·6171	0·6334	0·7501	0·8179	0·8884	0·9394	1·0577	1·1420
15	Net horse-powers applied to the shaft	6·0063	7·7942	10·4304	14·1424	19·3191	25·8158	32·2449	38·1883
16	Horse-powers absorbed by the friction of the load	0·4505	0·5845	0·7823	1·0606	1·4489	1·9362	2·4184	2·8041
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·2443	0·3318	0·4387	0·5688	0·7291	0·9472	1·2302	1·5978
18	Horse-powers expended in the slip of the screw	0·4642	0·6431	0·9122	1·3123	1·9301	2·9431	4·2351	5·4468
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	23·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw blades	4·03	4·26	4·20	4·02	3·77	3·67	3·82	4·19
22	Per centum of the net power applied to the shaft expended in the slip of the screw	7·73	8·25	8·75	9·28	9·99	11·40	13·13	14·26
23	Per centum of the net power applied to the shaft expended in the propulsion of the vessel	80·71	79·99	79·55	79·20	78·74	77·43	75·55	74·05

Table No. 3, containing the results of the experiments made with screw C, having the diameter 4¾ feet, the uniform pitch 5·136 feet, two blades directly opposite each other, and the fraction of the pitch 0·1785.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	10·43	11·16	11·83	12·54	13·47	15·42	17·78	19·43
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2795
5	Double strokes of engines' pistons and revolutions of the screw made per minute	110·2455	122·4942	134·3952	146·7752	159·7246	175·1186	192·2588	208·3610
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·2074	24·5542	29·5884	36·2747	45·1418	54·8683	62·4379	68·2274
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·2074	22·5542	27·5884	34·2747	43·1418	52·8683	60·4379	66·2274
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4406	1·6916	2·0691	2·7206	3·2356	3·9651	4·5328	4·9670
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·6204	0·7714	0·9297	1·1717	1·3115	1·5755	1·8977	2·2252
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	1·7882	2·2419	2·9078	4·0591	5·1986	7·2958	9·5734	11·4706
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	15·3582	17·8493	21·6818	26·3233	33·3961	40·0319	44·4340	47·5646
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·6912	8·5765	11·3239	15·1319	20·5598	27·3983	34·2298	40·5649
14	Horse-powers expended in working the engines, *per se*	0·6287	0·6986	0·7664	0·8370	0·9109	0·9367	1·0934	1·1883
15	Net horse-powers applied to the shaft	6·0625	7·8779	10·5575	14·3449	19·6489	26·3006	33·1334	39·3766
16	Horse-powers absorbed by the friction of the load	0·4547	0·5908	0·7918	1·0759	1·4737	1·9800	2·4850	2·9532
17	Horse-powers expended in overcoming the resistance of the water, by the screw-blades	0·1961	0·2691	0·3553	0·4628	0·5934	0·7800	1·0401	1·3239
18	Horse-powers expended in the slip of the screw	0·5644	0·7832	1·1132	1·6058	2·3578	3·6443	5·2471	6·8199
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	3·23	3·42	3·37	3·23	3·04	2·98	3·14	3·36
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	9·31	9·94	10·54	11·19	12·05	13·80	15·84	17·32
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	79·96	79·14	78·59	78·08	77·41	75·72	73·52	71·82

Table No. 4, containing the results of the experiments made with screw D, having the diameter 4½ feet, the uniform pitch 5·136 feet, two blades directly opposite each other, and the fraction of the pitch 0·1014.

No. of flas.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed	13·01	13·93	14·76	15·64	16 80	19·83	22·18	24·24
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	113·5172	126·2550	139·0130	151·8217	166·1714	183·3535	203·0254	221·0284
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	21·0166	24·2691	29·1565	35·8818	44·5813	54·2337	61·7576	67·5689
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	19·0166	22·2691	27·1565	33·8818	42·5813	52·2337	59·7576	65·5689
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	1·4262	1·6702	2·0367	2·5411	3·1936	3·9175	4·4818	4·9177
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	0·3765	0·4654	0·5649	0·6709	0·8048	0·9820	1·2011	1·3901
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2·2402	2·8037	3·6254	4·7977	6·4809	9·1043	11·9933	14·0317
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	14·9737	17·3298	20·9295	25·8721	32·1020	38·2299	42·0814	45·2294
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·8029	8·7372	11·5574	15·5338	21·1241	28 3549	35·7528	42·5856
14	Horse-powers expended in working the engines, *per se*	0·6474	0·7250	0·7928	0·8658	0·9467	1·0457	1·1578	1·2605
15	Net horse-powers applied to the shaft	6·1555	8·0122	10·7646	14·6680	20·1774	27·3092	34·5950	41·3253
16	Horse-powers absorbed by the friction of the load	0·4617	0·6009	0·8073	1·1001	1·5133	2·0482	2·5946	3·0994
17	Horse-powers expended in overcoming the cohesive resistance of the water by the screw blades	0·1216	0·1674	0·2234	0·2910	0·3816	0·5126	0·6959	0·8080
18	Horse-powers expended in the slip of the screw	0·7249	1·0091	1·4367	2·0765	3·0715	4·7591	6·9433	9·0483
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water, by the screw blades	1·98	2·09	2·08	1·98	1·89	1 88	2·01	2·12
22	Per centum of the net power applied to the shaft expended in the slip of the screw	11·78	12·59	13·35	14·16	15·22	17·43	20·07	21·40
23	Per centum of the net power applied to the shaft expended in the propulsion of the vessel	78·74	77·82	77·07	76·36	75·39	73·19	70·42	68·43

Table No. 5, containing the results of the experiments made with screw G, having the diameter 4½ feet, a pitch expanding in the direction of the axis from 6¼ feet to 7¼ feet, three blades, and the fraction of the pitch 0·3446.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed calculated for its mean pitch	9·89	10·58	11·22	11·89	12·77	14·63	16·89	18·48
3	Thrust of the screw, in pounds, by dynamometer	315·4	368 8	449·9	560·6	707·0	867·1	990·7	1,082·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4 8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	80·4029	89 1264	97·9321	106·9028	116·2882	127·3085	139·4847	151·0832
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	29·5351	34·3263	41·2660	50·7584	63·2041	76·9494	87·9421	96·4132
7	Pressure required to work the engines, *per se*, in pounds per square inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	27·5351	32·3263	39·2660	48·7584	61·2041	74·9494	85·9421	94·4132
9	Pressure absorbed by the friction of the load, in pounds per square inch of pistons	2·0651	2·4245	2·9449	3·6569	4·5903	5·6212	6·4457	7·0810
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	2·0068	2·4663	2·8557	3·4006	4·0260	4·8276	5·8003	6·8088
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2 3205	2·9027	3·7550	4·9562	6·7155	9·4364	12·4473	14·8807
12	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons	21·1427	24·5328	29·7124	36·7427	45·8723	55·0642	61·2488	65·6427
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·7714	8·7238	11·5236	15·4728	20·9581	27·9340	34·9780	41·5359
14	Horse-powers expended in working the engines, *per se*	0·4585	0·5083	0·5585	0·6097	0·6632	0·7260	0·7955	0·8616
15	Net horse-powers applied to the shaft	6·3129	8·2155	10·9651	14·8631	20·2949	27·2080	34·1825	40·6743
16	Horse-powers absorbed by the friction of the load	0·4735	0·6162	0·8224	1·1147	1·5221	2·0406	2·5637	3·0506
17	Horse-powers expended in overcoming the cohesive resistance of the water, by the screw blades	0·4601	0·6268	0·7969	1·0366	1·3350	1·7525	2·3070	2·9333
18	Horse-powers expended in the slip of the screw	0·5320	0·7377	1·0486	1·5114	2·2268	3·4256	4·9506	6·4108
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-b ades	7·29	7·63	7·27	6·97	6·58	6·44	6·75	7·21
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	8·43	8·98	9·56	10·17	10·97	12·59	14·48	15·76
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	76·78	75·89	75·67	75·36	74·95	73·47	71·27	69·53

Table No. 6, containing the results of the experiments made with the Griffith screw H, having the diameter, 4½ feet; a pitch expanding in the direction of the axis from 6⅞ feet to 7½ feet, three blades, and the fraction of the pitch 0·2034.

No. of line.		a	b	c	d	e	f	g	h
1	Speed of the vessel per hour, in geographical miles of 6,086 feet	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
2	Slip of the screw, in per centum of its speed, calculated for its mean pitch	11·60	12·44	13·20	14·01	15·06	17·31	20·06	21·99
3	Thrust of the screw, in pounds, by dynamometer	315·4	368·8	449·9	560·6	707·0	867·1	990·7	1,062·4
4	Horse-powers, by dynamometer, applied to the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
5	Double strokes of engines' pistons and revolutions of the screw made per minute	81·9597	91·0206	100·1646	109·5338	119·4457	131·42e9	145·0135	157·9068
	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.								
6	Mean gross-effective pressure on the pistons, in pounds per square inch	28·8521	33·4934	40·4021	49·7401	62·0121	75·5576	86·3277	94·5013
7	Pressure required to work the engines, *per se*, per sq. inch of pistons	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
8	Net pressure applied to the shaft, in pounds per square inch of pistons	26·8521	31·4934	38·4021	47·7401	60·0121	73·5576	84·3277	92·5013
9	Pressure absorbed by the friction of the load, in pounds per sq. inch of pistons	2·0139	2·3620	2·8802	3·5805	4·5009	5·5168	6·3246	6·9376
10	Pressure expended in overcoming the cohesive resistance of the water by the screw-blades, in pounds per square inch of pistons	1·3752	1·6964	2·0541	2·4567	2·9208	3·5371	4·3052	5·0530
11	Pressure expended in the slip of the screw, in pounds per square inch of pistons	2·7217	3·4129	4·4177	5·8426	7·9306	11·1656	14·7838	17·7043
12	Pressure expended in the propulsion of the vessel, in lbs. per sq. inch of pistons	20·7413	24·0221	29·0501	35·8603	44·6598	53·3381	58·9141	62·8064
	DISTRIBUTION OF THE ENGINE-POWER.								
	Absolute:								
13	Gross-effective horse-powers developed by the engines	6·7429	8·6930	11·5395	15·5355	21·1211	28·3164	35·6967	42·5508
14	Horse-powers expended in working the engines, *per se*	0·4674	0·5191	0·5712	0·6247	0·6812	0·7495	0·8270	0·9005
15	Net horse-powers applied to the shaft	6·2755	8·1739	10·9683	14·9108	20·4399	27·5669	34·8697	41·6503
16	Horse-powers absorbed by the friction of the load	0·4707	0·6130	0·8226	1·1183	1·5330	2·0675	2·6152	3·1238
17	Horse-powers expended in overcoming the cohesive resistance of the water, by the screw-blades	0·3214	0·4403	0·5867	0·7673	0·9948	1·3256	1·7802	2·2752
18	Horse-powers expended in the slip of the screw	0·6361	0·8858	1·2618	1·8248	2·7011	4·1845	6·1131	7·9717
19	Horse-powers expended in the propulsion of the vessel	4·8473	6·2348	8·2972	11·2004	15·2110	19·9893	24·3612	28·2796
	Proportional:								
20	Per centum of the net power applied to the shaft, absorbed by the friction of the load	7·50	7·50	7·50	7·50	7·50	7·50	7·50	7·50
21	Per centum of the net power applied to the shaft, expended in overcoming the cohesive resistance of the water by the screw-blades	5·12	5·39	5·35	5·15	4·86	4·81	5·10	5·46
22	Per centum of the net power applied to the shaft, expended in the slip of the screw	10·14	10·83	11·50	12·24	13·22	15·18	17·53	19·14
23	Per centum of the net power applied to the shaft, expended in the propulsion of the vessel	77·24	76·28	75·65	75·11	74·42	72·51	69·87	68·00

DISCUSSION OF THE RESULTS OF THE EXPERIMENTS IN THE PRECEDING TABLES.

Of the resistance of the hull at different speeds.—In the following table will be found the experimental resistances of the hull in pounds, for speeds varying by 0·1 geographical mile per hour between the speeds of 5·0 and 8·5 geographical miles per hour, both inclusive, and the ratio of these resistances as compared with the ratio of the squares of the respective speeds:

Speeds of the vessel in geographical miles per hour.	Squares of the speeds of the vessel, proportionally.	Resistances of the vessel at the different speeds.		Speeds of the vessel in geographical miles per hour.	Squares of the speeds of the vessel, proportionally.	Resistances of the vessel at the different speeds.	
		In pounds avoirdupois.	Proportionally.			In pounds avoirdupois.	Proportionally.
5·0	1·0000	315·4	1·0000	6·8	1·8496	644·7	2·0441
5·1	1·0404	323·3	1·0250	6·9	1·9044	676·3	2·1443
5·2	1·0816	333·2	1·0564	7·0	1·9600	707·0	2·2416
5·3	1·1236	344·1	1·0910	7·1	2·0164	739·6	2·3460
5·4	1·1664	356·0	1·1287	7·2	2·0736	773·2	2·4515
5·5	1·2100	368·8	1·1693	7·3	2·1316	805·8	2·5549
5·6	1·2544	380·7	1·2070	7·4	2·1904	836·5	2·6522
5·7	1·2996	397·5	1·2603	7·5	2·2500	867·1	2·7492
5·8	1·3456	414·3	1·3136	7·6	2·3104	895·8	2·8402
5·9	1·3924	431·1	1·3668	7·7	2·3716	920·5	2·9185
6·0	1·4400	449·9	1·4264	7·8	2·4336	946·3	3·0003
6·1	1·4884	470·7	1·4924	7·9	2·4964	967·0	3·0659
6·2	1·5376	490·4	1·5548	8·0	2·5600	990·8	3·1414
6·3	1·5876	513·2	1·6271	8·1	2·6244	1009·5	3·2007
6·4	1·6384	536·9	1·7023	8·2	2·6896	1027·3	3·2571
6·5	1·6900	560·6	1·7774	8·3	2·7556	1043·2	3·3076
6·6	1·7424	587·3	1·8621	8·4	2·8224	1057·0	3·3513
6·7	1·7956	616·0	1·9531	8·5	2·8900	1082·4	3·4318

During the experiments, it was remarked that the vessel's "trim," or her relative draught of water forward and aft, varied with every variation of speed, the bow rising and the stern falling as the speed increased. At the maximum speeds, the variation of the draught of water forward and aft was excessive. By this continual change or trim as the speed changed, the immersed solid of the hull was continually changing in form. Strictly, there was a succession of vessels, instead of the same vessel, at different speeds; and the resistances in the above table show, in reality, not the resistance of the same immersed solid at different speeds, but the resistances of immersed solids differing more or less from each other with every change of speed. The results of the experiments show that the resistance of these dif-

ferent immersed solids varied widely from the law of its proportionality to the squares of their speeds, increasing with increased speed sometimes less rapidly and sometimes more rapidly than due to that law, according as the actual immersed solid varied more or less favorably in function of resistance. To show this effect quantitatively, there has been placed in the following table, opposite the column of the vessel's speed, another containing the amount by which the resistance varied from the law of the squares, that amount being expressed in per centum of what the resistance would have been according to the law of its proportionality to the squares of the speeds. The prefixes of minus and plus indicate, respectively, whether the variation was less or more than the law:

Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.	Speeds of the vessel in geographical miles per hour.	Per centum of the resistance due to the law of its proportionality to the square of the speed, which the experimental resistance varied from that law.
5·0	.....	5·9	—1·84	6·8	+ 9·51	7·7	+23·06
5·1	—1·48	6·0	—0·94	6·9	+11·19	7·8	+23·29
5·2	—2·33	6·1	+0·27	7·0	+14·37	7·9	+22·81
5·3	—2 90	6·2	+1·12	7·1	+16·29	8·0	+22·71
5·4	—3·23	6·3	+2·49	7·2	+18·22	8·1	+21·96
5·5	—3·36	6·4	+3·75	7·3	+19·86	8.2	+21·10
5·6	—3·78	6·5	+5·17	7·4	+21·08	8·3	+20·03
5·7	—3·02	6·6	+6·43	7·5	+22·19	8·4	+18·74
5·8	—2·38	6·7	+8·07	7·6	+22·93	8·5	+18·75

From the above table it will be seen that the variation of the resistance of the hull from the law of its proportionality to the squares of the speeds was irregular in quantity, alternately increasing and decreasing. From the speed of 5·0 geographical miles per hour to that of between 6·0 and 6·1 geographical miles, the resistance varied in a lower ratio than that of the squares of the speeds, the ratio slowly decreasing until, at the speed of 5·6 geographical miles per hour, it was 3·78 per centum less than was due to the law. From the speed of 5·6 geographical miles per hour to that of between 6·0 and 6·1 geographical miles, the ratio slowly increased until, at the speed of between 6·0 and 6·1 geographical miles, the resistance was in exact

accord with the law. From the latter speed, the resistance rapidly increased above that due to the law, up to the speed of 7·8 geographical miles per hour, where it was 23·29 per centum greater than was due to the law. From the speed of 7·8 geographical miles per hour, the variation from the law decreased until, at the speed of 8·5 geographical miles, the resistance was 18·75 per centum greater than was due to the law.

Components of the resistance of the hull.—The power applied to the propulsion of the hull is divided between effecting the displacement of the water, that is to say, scooping out the watery furrow or trench measured by the area of the vessel's greatest immersed transverse section and the distance run, and overcoming the friction of the immersed external surface of the vessel on the water. If we suppose that surface to have remained constant during the experiments, which was very nearly the case, its frictional resistance can be calculated for every variation of speed. It will be, in fact, in the ratio of the squares of the speeds; and, by deducting it from the experimental resistance of the vessel, the remainder will be the resistance of the immersed solid of the hull in function of form. The calculation of this frictional resistance with exactness is impossible, on account of the continuously varying curvature of the immersed surface of the hull. The speed of this surface relatively to the water in contact with it, is nowhere as great as the vessel's speed, except for the keel and other flat sufaces parallel thereto. An approximation, however, can be made by considering the speed of the surface relatively to the water in contact with it to be less than the speed of the vessel, in the ratio of the base to the hypothenuse of a right-angled triangle whose base is represented by the half length of the water-line, and whose height is represented by the half breadth of the water-line. The resistance of a square foot of the immersed surface, moving with the velocity of 10 feet per second, will be taken at 0·45 pound, and to vary as the squares of the speeds. Applying this data, the speed of the surface is 8·26 feet per second when the speed of the vessel is 5·0 geographical miles per hour; hence the resistance of the 717 square feet of immersed surface of the hull, at that speed, is $\left(\frac{717 \times 0{\cdot}45 \times 8{\cdot}26^2}{10^2}\right) = 220{\cdot}14$ pounds.

(To be continued.)

ON THE MACHINERY OF THE VIENNA EXPOSITION.

By M. TRESCA.

[EDITORIAL NOTE.—The French Government printing house has just issued the first four volumes of the Reports upon the Vienna Exhibition made by the members of the international jury from France. These volumes contain fifty-two reports upon various branches of knowledge, most of them by men of distinction. We find in the *Revue Industrielle* an excellent editorial summary of the Report of M. Tresca, the distinguished engineer and metallurgist, upon the machinery of the exhibition; and believing that it will prove of interest to our readers, we give the following translation of it.]

M. Tresca states at the outset that the collection in the Machinery Hall was the greatest success of the Vienna Exhibition; and that moreover, it was far superior to any similar collection shown at any preceding one. He then gives his opinion as to the value of the exhibits made by the several countries, calling attention to the distinctive character of each of these subordinate exhibitions. The Austrian constructors, he thinks, vied with each other in producing the best, to the full measure of their ability. Less fully inspired, the Germans seemed to desire to dazzle by the quantity rather than by the quality of the machines they exhibited. The Americans, the French, and the English represented much better the actual state of industry in their respective countries, even in spite of the fewness of the pieces sent. The Belgians and the Swiss were very well represented, the sections devoted to these countries containing very many beautiful specimens of constructive mechanics. Except Italy and Russia, which countries made a creditable *debut* in mechanical industry, the other nations of the world exhibited nothing remarkable in mechanics. M. Tresca then enters upon a more detailed examination of the motors of all kinds, the pumps, the machine tools, and the machines in general. "The principal driving power of modern industry," he says, "the steam engine, was, of course, represented at Vienna under the most varied forms. But even in this great variety there could be discerned without difficulty a manifest tendency, more pronounced too than in 1867, to the employment, by preference, of a lifting valve for distributing the steam, in place of the slide valve to which we are accustomed in France. This tendency should be a means of instruction to us since it is entirely justified by the facts.

"France would have been the only country not represented in this advance, had it not been for the services of M. Farcot in connection with the machine exhibited in the Belgian section by M. Bede.

"There is no need of hesitation in asserting that in this direction we are behind the times. This arises, without doubt, from the fact that we have had, up to within a very few years, the most perfect and the most economical engines. Hence, our machine constructors have counted too much on the superiority of the old, and have ignored too much the real progress which has been made. This progress was inaugurated by the improvements made in the American Corliss engine, which has been the point of departure for all the more recent advances."

"While agreeing in general," says M. Fontaine, "with this opinion of M. Tresca, as to the great merit of engines of the Corliss kind, we yet believe that it would be a grave error to assume that they are capable of replacing all other sorts of engine. Their complication and the abruptness of their movements are serious inconveniences, especially in motors of small size. Moreover, the economy of steam secured by them is not as considerable as certain constructors of these engines would have us believe. I quote again here an opinion which I have given upon this subject in another place: For a power less than twenty horse, the ordinary expansion engines are excellent; from twenty to fifty horse-powers, we should prefer, according to the purpose to be subserved, either an eccentric engine or one working with a spring-catch; above fifty horse-powers, apart from special conditions which might modify this conclusion, we should give the preference to the Corliss system of cut-off, combined with the Woolf system. On the other hand, we believe that the French engine-builders are much less behind the times in the matter of such improvements, than M. Tresca supposes. M. Legavriau, to cite only a single example, has for some years manufactured Corliss engines; and if he did not exhibit them at Vienna, it was undoubtedly only because he was too busy filling orders for them, immediately after the war."

"We are, on the contrary," continues M. Fontaine, "entirely in accord with M. Tresca, when he says in speaking of steam boilers:—

"'If any one were to form his opinion of the present state of the art of constructing steam boilers from an attentive examination of the numerous contrivances represented at Vienna, this opinion would

be strangely erroneous. While the manufacturer should seek simple combinations, such as are readily used and easily taken care of, the exhibitor is striving to complicate steam generators beyond measure, and in a thousand different ways. They even attempt to explain the reason of each peculiarity which they adopt; but their assertions are not based upon any satisfactory experimental results. It would even seem that they had sacrificed everything, blindly and without reason, to the single end—and that too, at least in fixed boilers, a secondary one—of multiplying as largely as possible the extent of the heating surface, in relation to the whole volume of the boiler.' "

The only point of progress noticed by M. Tresca in his examination of steam generators, is the employment of the Bérenger apparatus for avoiding incrustations.

In the paragraph upon locomotives, he gives a well-merited compliment to the freight engine exhibited by the Creusot Works, summarily describing the advantages of the *contrevapeur*, and calling attention to the general tendency to make the fire-boxes, and especially the grates, very large.

M. Tresca passes rapidly in review the portable engines exhibited, as well as those which are semi-portable; and also, traction engines. In relation to the latter, he considers the only really practicable ones are those of Aveling and Porter; but he does not believe that the india-rubber tires, so much puffed during late years, have given very satisfactory results.

Among the accessories to the steam engine, the author places in the first rank the products exhibited by Schœffer & Budenburg, of Magdebourg; a firm employing nearly two thousand workmen, and manufacturing detached articles, such as manometers, injectors, regulators, cocks, etc.

Under hydraulic motors, he remarks that the observed progress seems to have been rather in the direction of broader applications than in that of a more careful study of the theory of turbines. The hydraulic works at Schaffhausen and Belgarde are really on a magnificent scale.

Coming now to the examination of machines for raising water, the exhibits of MM. Bon & Lustrement, Tangy Bros., Edoux & Megy, and Etcheveria & Bazan, are cited with commendation; among pumps, the noticeable machine of M. Prunier is given as a model worthy of being copied; the direct-acting steam pumps are criticised

because of their feeble effectiveness, the rotary pumps of MM. Dumont and Edoux are specially mentioned; and the fire engines are referred to as containing the elements of a complex problem yet to be resolved.

M. Tresca begins his report upon injectors in this way: "Although the diploma of honor voted to M. Giffard, without any opposition and with perfect unanimity, by the jury on machines, was suppressed by an ulterior vote, which we may be permitted to regret; yet it is impossible, notwithstanding, not to consider the invention of this injector as one of the most remarkable and the most highly valued of French inventions; an invention to which, since then, a large number of very important improvements have been made."

"We have already noticed," says M. Fontaine, "the injustice done to M. Giffard, but we return to the subject willingly, in order to protest still again against the manœuvres employed before the Council of Presidents in order to prevent the giving to our countryman of the just reward of his beautiful invention."

The Report goes on to consider next the machine tools which were exhibited, including those for working metals, wood, and stone. In the first section, M. Tresca mentions with high commendation, MM. Sellers, Heilmann, Ducommun & Steinlen, Sharp, Stewart, Deny, Arbel, Haswell, and Brunon Bros. In the second section, he speaks especially of the machines exhibited by MM. Perin and Arbey; and in the third, he mentions those of MM. Holmes & Taylor, Dubois & Francois, Mangé & Lippmann, and Tilghman.

"We would like to be able to quote here all that part of the Report which relates to machines designed for working metals. Unfortunately, space for this fails us, and we must be contented with reproducing here three passages concerning exhibits which received the diploma of honor:

"The number of the designs—as thoroughly conceived as they were ably executed—which constituted the important exhibit of M. Sellers, constituted the most beautiful series of the entire Exhibition. M. Sellers has, however made no modifications in the arrangements of his lathe with variable velocities, by means of friction plates, which had attracted attention in 1867; nor has he changed the mode of action of the principal parts of his automatic machine for cutting gears, which is certainly the most complete machine of its kind in

use. But, nevertheless, his exhibit presents in a high degree the character of general perfection which has placed him, since 1867, in the front rank among the constructors of machine tools.

"The beautiful machine tools of MM. Heilmann, Ducommun & Steinlen (formerly Dubied & Ducommun), are as well appreciated in foreign countries as in France. It is well-known that no care is spared in their construction, and that more efficient lathes and more powerful planing machines are nowhere to be found. A single regret mingles with the unanimous decision which gave them deserved justice; and that is that this decision is to be counted among the number of successes of our neighbors, while in fact the industry developed by MM. Heilmann and Steinlen is wholly French by its origin, its progress, and its development, as well as by the talent and the energy of its directors. Without giving up a single one of the rare qualities which distinguish the fine tools which issue from this establishment, and continuing still to cement all those parts of their machines which are liable to become deformed by strain, MM. Heilmann and Steinlen, the actual directors, constructed for the exhibition a series of typical stages of the different kinds of machines. Each of these series, continued even up to the most powerful tools, is in perfect accordance with the widely varied demands of modern industry, and forms an assortment excellently well adapted to the various needs of the workshop. M. Steinlen has also rendered a signal service in the construction of machines by his study of the metric types of the dimensions of the screw threads of Whitworth, thus expressing their values in sub-divisions of the meter, and improving at the same time, by a better selection of the ratios, screws of small dimensions.

"Another industry, also entirely French, is that of M. Deny, which has for its principal specialty, the construction of all tools required in the manufacture of the thousand small metallic articles which are made in Paris by artisans at their own homes. By the side of the stamp employed in the manufacture of the links of watch chains made of brass, and of all shapes, there was exhibited some specimens of these products, which had a great success at the Exhibition. The manufacture of stamped thimbles of copper for uniting tubes together, the friction press worked by steam, the machine for the manufacture of cartridges, did not have the same importance before the jury, that was given to his method of constructing filter-presses for paper or for beet-root pulp. This is effected by means of stamped plates with beveled

channels, forming on the opposite face straight grooves having exactly the same size within a few tenths of a millimeter. These plates rolled into the form of a cylinder, always preserve the same exactness in the size of the orifices, and in this way constitute strainers excellently well suited for conducting continuous operations. The construction of these plates by M. Deny has rendered it practicable to employ various systems of continuous filter-presses, which are so important in increasing the rapidity with which, in our manufactories of indigenous sugar, the beet-juice can be extracted."

M. Tresca concludes his report with a review of the machines required in the textile arts, in various special manufactories, in printing, working leather, and in making belts; of sewing machines, of kneading machines, of grist-mills, of the apparatus employed in chemical and sugar industries, in distilling, in the manufacture of aerated waters, in breweries, and in the manufacture of candles; and of the apparatus which is used in the development of physical phenomena.

Under the head of sugar industry, there is a very favorable notice of the apparatus of Fives Lille, and a mention of the *essoreuses* with adherent motors of M. Buffaud. Under distilling, there is a compliment paid to the Savalle apparatus; and under the manufacture of aerated waters, there is much said in praise of the inventions of M. Hermann Lachapelle.

M. Tresca closes his report thus: "We see by this rapid review of the principal classes of machines exhibited, that there has not been very great progress in the mechanic arts since the Exposition Universelle of 1867. Their domain, however, has been enlarged, and the methods of construction have attained to a higher perfection. The more general utilization of the forces of nature and their application to the grand civil engineering enterprises of the day, is, among all the new advances, the one which at Vienna, presented the greatest development.

"We cannot forget that France has always remained in the front rank of mechanical industry, side by side with England, the United States, Belgium and Switzerland."

"We can add here but a word. No one has done more than M. Tresca himself, to sustain the rights of our manufacturers and to make known and recognize the supremacy of France in a host of industries. It is to his thorough knowledge of machinery that he owes the influence which enabled him to become so effective a member of the international jury.

Chemistry, Physics, Technology, Etc.

ACCOUNT OF SOME EXPERIMENTS MADE FOR THE PURPOSE OF COMPARING THE INDICATIONS OF TWO CASSELLA'S AIR METERS.

By C. B. Richards, M.E.

In some branches of physical research, and in all investigations which relate to the warming and ventilation of buildings, mines, etc., it is necessary to determine the quantity of air which flows through apertures and channels of various kinds; and, in order that incorrect conclusions may be avoided in such cases, it is important to know how great dependence can be placed on the instruments used for making these determinations. It is, therefore, believed that the following account of a series of tests of a kind of anemometer which is extensively employed, will be of value to those who may contemplate using these or similar instruments, by calling attention to some of the difficulties which attend their use.

During the last two winters, the writer of this article was engaged in conducting an extensive series of experiments for the purpose of determining the relative efficiency of various steam heaters for warming air, which will be made the subject of reports to the Smithsonian Institution and the Commission for the new Connecticut State Capitol, under whose auspices they were made. In these experiments a "Cassella's Air Meter" was employed as one of the means of measuring the quantity of air which passed through the heaters.

The results obtained from the indications of this meter were unsatisfactory and inconsistent, and, after the heating experiments were concluded, it was decided to compare the indications of two of the meters placed under conditions as nearly similar as practicable, in order to ascertain whether the results obtained from them would coincide. Arrangements were accordingly perfected for these new experiments, and the meters were tested together. Under these circumstances, *the results failed to agree*, and the experiments appear to have demonstrated that the meter indications depend to so great an

APPARATUS IN WHICH THE METERS WERE TESTED.

FIG. 1.

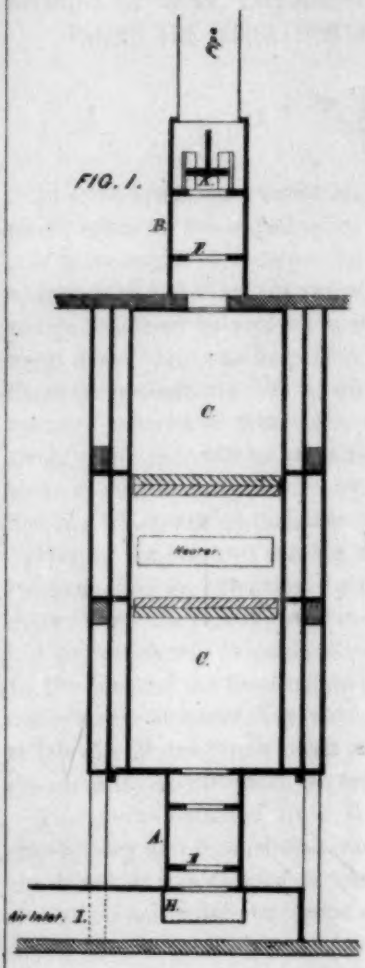


FIG. 2.

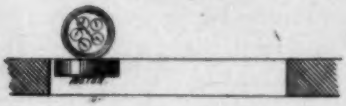
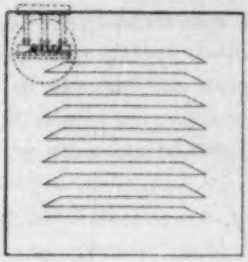
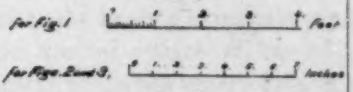


FIG. 3.



Scales,



extent on the temperature of the air and on imperceptible variations in the conditions under which the meters are placed, the effects of which cannot be predicted, but which are important, that the results are liable to lead to conclusions which may be far from correct, at least when the meters are used in comparatively small apertures.

The meter tests will be fully described in order that the correctness of this opinion may be verified or criticised.

The Cassella Meter was described in an illustrated article in the JOURNAL OF THE FRANKLIN INSTITUTE, vol. xci, page 326. The two meters employed in the tests were numbered 136 and 327. The former was kindly loaned for the purpose by President Morton of the Stevens' Institute of Technology, while meter 327 was imported by the writer directly from Cassella, in 1873, and resembled the first in every essential detail.

The meter trials were made in the apparatus which was used in testing the heaters, one meter being located and kept running in the place where a meter was used during the heating experiments, while the other was in operation in a different part of the apparatus, where it was subjected to the same conditions, as nearly as possible.

In the accompanying plate, Figure 1 is a vertical section of all the principal parts of the apparatus.

C is a large chamber with air tight walls, about 9 feet high, in the centre of which the steam heaters were placed when tested. Beneath this chamber, and opening into it, is a box *A*, provided with a glass front and a horizontal diaphragm which has through it an aperture *E* exactly 10 inches square. A similar box *B* is situated above the chamber *C*, and this box also has a glass front and a diaphragm with an aperture *F* of exactly the same size and shape as *E*. Other diaphragms having square apertures from 10 inches to 12 inches diameter are arranged above and below the apertures *E* and *F* and serve to direct the air through these.

Beneath the box *A*, and in communication with it, is a chamber *H*, the bottom of which is formed of perforated tin, which acts as a diffuser to the entering air to prevent irregular currents through *E*. The chamber *H* is immersed in a channel *I*, into which air was driven by a fan-blower during the experiments. A valve *K* in the upper part of the box *B*, served to regulate the quantity of air which passed through the whole apparatus.

One meter was placed in each of the two apertures *E* and *F*, being suspended from above so that the wind-wheel of the meter entered the aperture in the manner shown in Figures 2 and 3, in which the parts shown are drawn to a larger scale than in Figure 1.

Both meters were attached to mechanism by which they were caused to travel back and forth, with slow uniform movements, over the whole area of their apertures, in zigzag paths which are indicated in Figure 3 by a fine line. The time occupied by a meter in going over the entire area of the aperture was 3 minutes. The machinery for producing these movements need not now be described; its parts were so arranged as not to interfere essentially with the currents of air, and were exactly alike in both boxes. It is believed that, by the use of this device, the meters were presented to the different parts of the apertures in such a manner that the average velocity of currents of air through the apertures ought to have been correctly recorded by the meter if it could have been done under any circumstances.

Several thermometers, for which tables of corrections had been obtained by experiment, were hung in the boxes *A* and *B*, and an aneroid barometer and Edson's hygrodeik were placed in the lower box. All the instruments could be read by looking through the glass fronts, without opening the boxes. The following method was employed in the experiments:

The fan-blower, already referred to, was kept in motion, and air, which was taken from a room whose temperature could be regulated, was blown into the channel *I*. The direction of the air after passing the perforated bottom of the chamber *H* was upward through both the boxes and all the square apertures.

At first meter 327 was placed in the upper box *B* in the aperture *F*, and meter 136 in the lower box in the aperture *E*. Warm air was then caused to pass through the apparatus at as nearly a uniform velocity as possible, for 15 minutes, and the readings of both meters, of the barometer, the thermometers, and the hygrodeik were observed. Several experiments with various velocities of the air were tried while the meters remained in these positions, after which the meters were exchanged as to place, 327 being moved to the lower box and 136 to the upper box. A series of trials was then made, under these changed conditions, with warm air at various velocities, after which a succession of trials, each also lasting fifteen minutes, was

made with cold air at various velocities, and with the meters exchanged back and forth from one box to the other.

Repetitions of the various tests were made, and all the results have been arranged in the accompanying tables I and II. The meters were in all cases kept continually traveling over the areas of the apertures in the manner described.

The temperatures of the boxes *A* and *B* differed somewhat, owing to the passage of air over the surfaces of a heavy cast-iron "radiator" which, in the meter experiments, remained in the chamber *C*, but was not supplied with steam. As this mass of iron was colder than the warm air used, and warmer than the cold air, the air was either cooled or warmed a few degrees in passing from one meter to the other.

In tables I and II, the experiments are numbered in the succession in which they were made. Column 10 gives the ratios between the absolute temperatures T' and T of the air at meters 327 and 136 respectively. The velocities of the air through the 10 inch square apertures, given in columns 8 and 9, are from the observed meter readings, corrected in accordance with the tables, which the manufacturer furnishes with each instrument.

In column 11 are the ratios between the quantities of air, by weight which, according to the meters, passed through the apertures in a given time; the quantities W' and W being calculated from the corrected velocities, the temperatures of the air at the two meters being, of course, taken into account. The formula by which these last ratios were calculated is

$$\frac{W'}{W} = \frac{V'}{V}\frac{T}{T'}$$

The values of the letters and ratios are found in the columns of the tables.

Although the volume of the air was changed slightly between the two meters, by the change in its temperature which occurred in the chamber *C*, yet the same quantity of air, by weight, passed both meters at the same instant, for as the walls of the apparatus are air-tight, no air was added to or taken from the quantity which entered the chamber *H*, in its course through the apparatus. If, therefore, the indications of the two meters, when modified by the proper corrections, had coin-

cided, the ratios $\frac{W'}{W}$ in column 11 would have been unity in all cases, and the deviations from unity which the numbers in this column show, indicate directly the discrepancies between the two meter results. These discrepancies are more plainly shown in columns 12 and 13, from which we learn that, according to the corrected readings, when meter 327 was in the upper aperture, it indicated, at low velocities, *with warm air*, 29 *per cent. more* than 136 did in the lower aperture; while *with cold air*, it indicated 30 *per cent. less*. But, when their relative positions were exchanged, and 327 was placed in the lower aperture, it indicated *with warm air*, 30 *per cent. less* than 136 did in the upper aperture, but *with cold air*, 27 *per cent. more*.

The conditions in which the meters were placed were, as nearly as could be ascertained, alike in both apertures, except in respect to temperature; and all the conditions were certainly as carefully observed in these experiments as they would be in most experimental uses of this kind of instrument. The results of these experiments then seem to show that the indications of the two meters differed so widely, and in such a manner, as to destroy confidence in their usefulness when they are employed under circumstances at all similar to those described.

The variations in the meter indications do not seem to follow any easily recognized law.

Colt's Armory, Hartford, Conn., May 29th, 1875.

Intensity of Colored Lights for Illumination.—Some experiments have recently been made at Trieste with a view to testing the intensity of colored lights, and of white light with different oils. While no doubt was entertained that the best effect with lights at a distance was had with white light, and the next best with red, it was desired to ascertain the comparative utility of other colors for harbor lights. Small hand lanterns were used with white, red, green, deep, and dark blue glasses. With the white were used American petroleum, parraffin, and olive oil. At half a mile distance the dark blue was quite invisible, and the deep blue hardly visible (showing their uselessness for illumination at sea). The experiments made to a distance of two nautical miles, gave the following results: 1. That white light with petroleum is more intense than with parraffin,—the latter also went out several times, so it lacked the necessary certainty. 2. That among the lights with olive oil, the red was the brightest—after the white—and the green (Bohemian make) after the red. The green light may at short distances be made to alternate with the white.

TABLE I.—Meter 327 in the Upper Aperture F, and Meter 136 in the Lower Aperture E.

Number of the Experiment.	Condition of the air.				Velocity of the air per minute.				$\frac{T}{T'}$	$\frac{W'}{W}$	Excess	
	Barometric pressure.	Moisture. Degree of Saturation.	Temperature Fahrenheit, at		Observed from		Corrected by Cassella's tables for				327 over 136	136 over 327
			Meter 327	Meter 136	Meter 327	Meter 136	Meter 327	Meter 136				
1	2	3	4	5	6	7	8	9	10	11	12	13
	Inches.	Per cent.	°	°	Feet.	Feet.	Feet.	Feet.			Per cent.	Per cent.
5	30·16	...	71	76	104	84	137	109	1·01	1·27	27	
6	30·16	...	70	74	110	87	143	112	1·01	1·29	29	
24	30·23	37	75	79	121	102	156	127	1·01	1·24	24	
4	30·16	...	71	79	135	115	170	139	1·01	1·24	24	
3	30·16	...	70	79	187	183	225	208	1·02	1·13	13	
1	30·16	...	61	74	201	211	240	230	1·02	1·07	7	
2	30·16	...	67	77	206	208	245	227	1·02	1·10	10	
25	30·23	37	78	85	218	218	257	238	1·01	1·09	9	
19	30.37	26	87	92	233	235	273	253	1·01	1·09	9	
18	30·37	26	86	91	235	232	276	250	1·01	1·12	12	
26	30·23	37	81	88	266	280	308	297	1·01	1·05	5	
17	30·37	26	85	90	275	289	317	305	1·01	1·05	5	
31	29·72	66	44	39	55	97	86	122	0·99	0·70		30
14	30·38	72	43	36	68	104	99	129	0·99	0·76		24
30	29·72	66	44	41	69	114	100	138	0·99	0·72		28
15	30·38	72	40	34	89	125	121	148	0·99	0·81		19
29	29·72	66	44	42	106	149	140	171	1·00	0·82		18
16	30·38	72	39	34	107	147	141	169	0·99	0·82		18
28	29·72	66	44	42	110	149	143	171	1·00	0·83		17
27	29·72	66	44	41	122	108	157	180	0·99	0·87		13

TABLE II.—Meter 327 in the Lower Aperture E, and Meter 136 in the Upper Aperture F.

Number of the Experiment.	Condition of the air.				Velocity of the air per minute.				$\frac{T}{T'}$	$\frac{W'}{W}$	Excess	
	Barometric pressure.	Moisture. Degree of Saturation.	Temperature Fahrenheit, at		Observed from		Corrected by Cassella's tables for				327 over 136	136 over 327
			Meter 327	Meter 136	Meter 327	Meter 136	Meter 327	Meter 136				
1	2	3	4	5	6	7	8	9	10	11	12	13
	Inches.	Per cent.	°	°	Feet.	Feet.	Feet.	Feet.			Per cent.	Per cent.
7	30·16	...	74	69	63	109	94	133	0·99	0·70		30
8	30·16	...	77	70	104	141	137	164	0·99	0·82		18
23	30·23	37	82	76	107	149	140	171	0·99	0·81		19
22	30·23	37	84	78	133	172	168	193	0·99	0·86		14
9	30·16	...	83	73	174	194	212	214	0·98	0·97		3
10	30·16	...	84	76	213	230	253	248	0·98	1·00	0	0
21	30·23	37	85	78	218	232	257	250	0·98	1·01	1	
20	30·23	...	84	76	274	269	317	286	0·98	1·09	9	
32	29·73	76	39	44	74	60	106	87	1·01	1·23	23	
13	30·38	72	34	41	88	84	120	109	1·01	1·12	12	
33	29·73	76	40	44	102	82	135	107	1·01	1·27	27	
12	30·38	72	30	39	145	132	181	156	1·01	1·19	19	
34	29·73	76	42	44	146	120	181	144	1·00	1·26	26	
11	30·38	72	30	45	176	165	213	186	1·03	1·18	18	
35	29·73	76	43	45	188	150	226	172	1·00	1·32	32	

SYMPATHETIC VIBRATION.*

By Henry A. Rowland, C. E.

I. *Experimental.*

Among the most curious mechanical facts which we observe in nature, those which we class under the head of sympathetic vibration seem to me to stand forth quite prominent, and the more we study them the more we are convinced of their wide-spread nature.

We all learn the fundamental facts with regard to this subject in our childhood when we go out to "take a swing." Here one person sits on a board so that he can vibrate back and forth in times of nearly equal duration, while another person pushes him as he goes forward, but stops pushing as he comes back. In this way the work done by the person pushing is gradually stored up in the other, and the amplitude of his vibration increases until the work done is equal to the work spent against the resistance of the air, when no further increase is obtained.

In this case we observe that to have the vibration regular and as great as possible, the pushes must be regular and made only while the swing is going forward. If the pushes are irregular the vibrations will be irregular and will never obtain great amplitude. These principles hold in all cases of sympathetic vibration, as we shall see as we proceed. To illustrate this case experimentally we can use the method which I have already described some years back: Let us make two pendulums of equal length by hanging bullets to fine silk thread and let us hang the pendulums near each other, but so far apart that they can swing freely; and, further, let us connect the strings of the pendulums near the top by a piece of fine yet stiff wire. On now drawing aside either of these pendulums in the plane containing the two and letting it vibrate, the other soon commences to move, and its excursions to either side increase more and more until we are soon surprised to observe that its vibrations have greater amplitude than those of the first; and soon after the first pendulum comes to rest and the second has entirely absorbed its motion. But soon the first moves once

* Read before the Pi Eta Scientific Society of the Rensselaer Polytechnic Institute, Troy, N. Y., and communicated by the author.

more, its motion increases and it is not very long before it has regained it all once more, and were it not for friction, the system would now be in exactly its initial state. And so these two pendulums keep on exchanging motion until friction has destroyed it and the vibratory motion of the pendulums becomes the motion of heat. But if one of the pendulums is a little longer than the other the motion is no longer exchanged, but the second one still moves to some extent. But it soon comes to rest once more only to commence again.

These phenomena can also be observed on a sonometer having two strings tuned in unison. On causing one to vibrate the other soon commences, and if we withdraw the bow it will absorb nearly all the motion from the first string only to give it back to it once more after an equal interval of time. If the strings are not exactly in unison the second will still respond to the first but it will not absorb *all* the motion from the first.

In the experiment of the pendulums, if we make one of the pendulum balls larger than the other and then regulate the lengths until the proper ones are reached, the motion will still be exchanged, provided there is not too great difference of size. It is interesting to observe in this case that when the small ball has the motion the amplitude of vibration is larger than when the large ball has it, and this, I consider, to be a beautiful illustration of the conservation of energy.

By taking measurement we might prove by experiment that the kinetic energy of a body is measured by the half product of the mass by the square of the velocity, a proposition which, I am sorry to say, has been recently disputed by a writer in a journal of repute. When one of the balls is made very large, the motion is no longer exchanged, owing to the resistance of the air on the small ball. This last case corresponds exactly to the case of the swing.

All these experiments can be repeated in a most excellent manner on bodies swinging by torsion. Plate I, Fig. 1 represents two balls of considerable weight, hung so that they can swing freely by torsion, in nearly equal times. Near the top of the wires are attached two light cross pieces, *c* and *d*, at right angles to the plane containing the wires, and these are joined together by the threads, *b* and *k*. When properly regulated the motion is exchanged in the most perfect manner, and as the resistance is less than in the case of pendulums, the motion is kept up longer. The wires for torsion can evidently be replaced by a bifilar suspension.

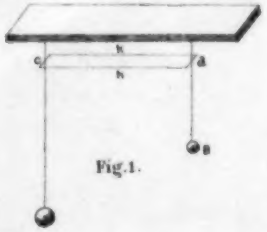


Fig.1.

Fig.2.

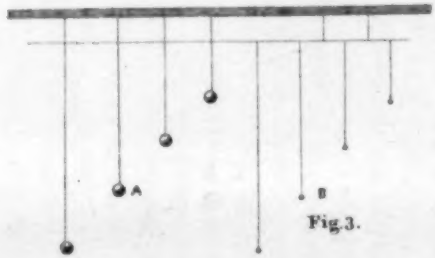


Fig.3.

Fig4.

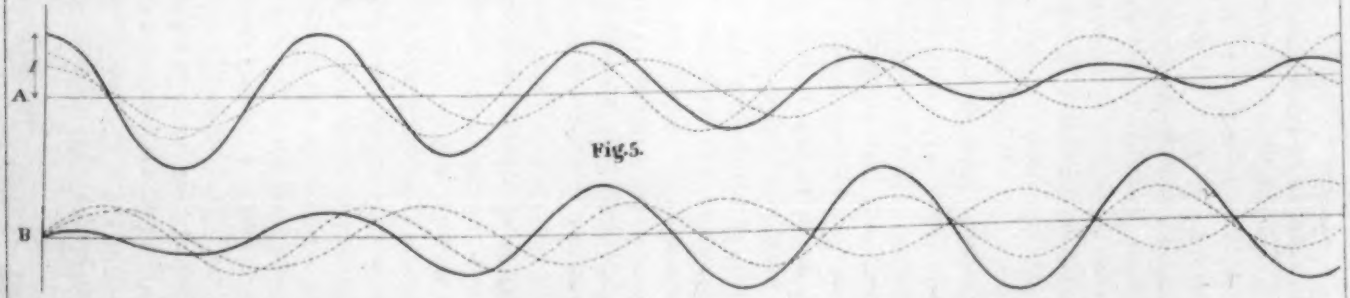


Fig.5.

We can modify the above by suspending one ball from the other, as in Plate I, Fig. 2. Here the ball A is very heavy, and is suspended by a quite thick wire, and the ball B is light and is suspended by a thin wire, so that the time of vibration of A is nearly the same as that of B. The first ball is so heavy that its vibrations are little affected by B and it becomes a nearly fixed point for the suspension of B. Hence, the two balls are in a measure independent of each other. The results with this are very curious. When properly adjusted, a vibration of A through a few degrees will soon cause the small ball to oscillate through one or more complete revolutions. The motion is exchanged in this case very completely. The suspension of A can be bifilar if desired.

If the wires in this arrangement are replaced by threads, we get still other effects; for when the lengths of the threads are properly adjusted, that is, are of nearly equal lengths, we can swing either of them as a pendulum and the other will answer to it. Thus a motion of the large ball through a small fraction of an inch may, in time, cause the small ball to vibrate through a foot or more, and the two will continue to exchange motion for some time. If one of the balls is made to describe an ellipse, the other will follow it after a time on a larger or smaller scale as the case may be.

Let us now, before proceeding further, glance over the laws which we can glean from the above experiments. We see then, in the first place, that to have bodies respond to each other to any great extent, the times of their vibrations when free from each other must be *nearly* the same. It is often stated that they must be *exactly* the same, but I shall show when we come to the mathematical discussion that the times must differ slightly. In the second place the two bodies must be connected in some way so that *each must influence the other's vibrations.* We also observe that except for friction and other losses the energy of the system is a constant quantity, so that the two bodies are never vibrating to their fullest extent at the same time, but when one has the greatest motion the other has the least. And lastly, on closely examining the vibrating bodies, for which purpose the pendulums are the best, we perceive that the body to which motion is being given always lingers behind that which is giving it motion.

As we study other cases we shall see that these laws are general and apply to all kinds of sympathetic vibration.

In all the cases which we have hitherto considered, the connection between the vibrating bodies has been of the most obvious character; in the case of pendulums it was the wire between them, and in that of the two strings it was the bridge over which those strings were strung. But other methods of connection are at hand: thus we could attach magnets to the two pendulums which by their mutual repulsion would take the place of wire. But the best way of trying this experiment is to prepare two magnets so as to vibrate in nearly equal times by loading the one which vibrates too fast until it is adjusted; if they have equal moments of inertia the times of vibration must be exactly equal. They may then be hung east and west from each other or in other positions if preferred, and they will then be found to exchange their vibratory motion in a remarkable manner.

In the well-known experiment where one tuning fork is made to respond to another of equal pitch sounded near it, the medium of communication is the air in which waves are formed. But it is not so easy to see how the vibrations of the primary fork are effected by those of the secondary one. When, however, we come to study the matter, we shall see that the secondary fork also gives out waves in such a phase that when they strike on the primary fork they diminish its vibrations. The motion is not generally exchanged in this case, because by far the greatest amount of the energy of the forks goes to producing waves in the air rather than motion in each other; but it is probable it does take place to some extent.

The science of Acoustics furnishes many other beautiful illustrations of sympathetic vibration. Thus when we bring a tuning-fork near an open vessel of proper size, containing air, we perceive a strengthening of the sound, which is called resonance. The air in the vessel in this case is the vibrating body, and could we make sufficiently delicate experiments it would appear that the vibration of the tuning-fork was affected by that of the air. This is shown in the case of the reed-pipe, with tube attached, and which is nothing but a modified case of resonance. Were the reed free its time of vibration would be fixed; but when it is in place the tone given out depends not only on the reed, but also on the pipe, thus showing that they modify each other's vibrations.

A striking case of sympathetic vibration is seen in sensitive flames, smoke-jets, and jets of water, for a description of which I refer the reader to Prof. Tyndall's excellent work *On Sound*.

Our knowledge of sympathetic vibration is of much use to us where we wish to analyze a given compound vibration and pick out its elements; for it can be demonstrated mathematically that in no matter how irregular a manner a body may vibrate, we may still suppose its motion to be made up of a number of regular vibrations, superimposed on each other. Having such a vibration, then, we are required to find its component vibrations. To produce the irregular vibration in question, we can construct the apparatus shown in Plate I, Fig. 3.* To the lower edge of a board four or five feet long we suspend a number of pendulums, varying in length from five or six inches to about twenty inches, and weighing an ounce or two each. We then select a stiff wire—steel being the best—of about No. 17 gauge, and as long as the board, and hang it beneath the edge of the board by fine threads, an inch or so long. We then tie the pendulum threads to the wire at the points where the two cross.

On now starting a number of the pendulums at the same time, the wire is drawn hither and thither by the conflicting pulls of the pendulums, and if there are many of these one can hardly detect any regularity in its motion; but it is regular, not only because it is the sum of a number of regular motions, but because we can again decompose it into its elements; for, on now hanging on the wire several light pendulums, they will be agitated by the motion, but none of them will vibrate to any extent unless its time of vibration is similar to that of one of the heavy pendulums. In this case it will pick out that vibration, which is similar to its own, and will soon attain great motion.

In the apparatus shown in Fig. 3, the pendulums *B* should be adjusted until the time of vibration of each equals that of the corresponding pendulum of *A*, after the whole apparatus is together, and while each pendulum is in place; and I may warn those who wish to construct it, that it must be done with care.

A beautiful apparatus of this same nature has been described by Prof. Mayer. Having arranged an organ pipe in its proper position, with respect to some tuning-forks, he attaches a prong of each of them to one point on the face of the organ pipe by means of a silk fibre. The air in the organ pipe has, in general, a compound vibra-

* This was first described by me in the JOURNAL OF THE FRANKLIN INSTITUTE, Vol. xciv, p. 275, 1872.

tion due to its dividing into nodes and loops, and so gives the point on the organ pipe a motion similar to the wire in the pendulum experiment, and the elements of this motion are shown by those tuning-forks which vibrate.

As a general rule, when a note is struck upon any instrument, we obtain besides the fundamental note a number of other notes of a higher pitch mingled with it, and called over-tones or harmonics. In some cases the ear is able to detect these, but in others this is not possible. But Helmholtz has found a method, based upon sympathetic vibration, by which we can do this in all cases. For this purpose he uses what are known as resonance globes, which are merely globes of different sizes, with two openings, one for placing to the ear, and the other for the admission of the sound. Should the sound contain any component vibration to which the air in the globe can vibrate, it can be instantly perceived by the person using the globe.

Kœnig places a number of these globes on a stand together, and the vibration of the air in them is shown by the flickering of gas-jets attached to them in a certain way.

We have now come to another part of our subject of a somewhat different nature from that we have been considering. Hitherto the bodies we have used have been, for the most part, capable of vibrating in only one given time; but, as a general rule, most bodies are capable of vibrating in a number of ways. Thus a stretched string can either vibrate as a whole, or can divide up into a number of different parts, each of which vibrates; and so from a given string we can obtain a large number of notes.

Such a body as we have described is capable of sympathetic vibration as well as one of the other kind, and will, if possible, accommodate itself to the vibrating body.

Thus two strings of a sonometer, when tuned to unison, will respond to each other, not only when sounding the fundamental note, but also when the first string is divided in any way; and it is easily shown by placing paper riders upon the wires that they are both divided in the same manner.

This is also the case with the vibration of plates, as may be shown by sprinkling sand on them to bring out the nodal lines. When two equal plates are placed above each other, with only a few inches of air between the two, and the upper plate is caused to sound by a

violin bow so as to produce a certain configuration of nodal lines on that plate, we shall perceive, on taking away that plate, that the sand on the plate below is arranged in exactly the same series of nodal lines.

Melde's experiment, of causing a string to vibrate by attaching it to one of the prongs of a tuning-fork, is also a case in point.

When small vessels of different shapes, containing mercury, are placed on the cases of musical instruments capable of giving out a continuous sound, the surface will divide up in a series of stationary waves, intersecting the surface in the most beautiful manner. This effect varies with the shape of the vessel and note sounded.*

Some of the principles of sympathetic vibration can be applied to the giving to and receiving of vibrations from air. Free air can vibrate in an infinite number of ways, and we may not at first see how it comes under the head of sympathetic vibration. However, the connection between the two will be apparent by simple reasoning.

In Fig. 4, let $G\,B$ be a brass rod, firmly fixed at A, and with a light piston, B, at one end loosely fitting the glass tube, $B\,F$. On now causing the rod to vibrate longitudinally by means of a piece of cloth containing resin, and having sprinkled some light powder in the tube, if we place a piston at some point, C, the air in the tube at $B\,C$ will vibrate in response to the rod, as shown by the motion of the dust. This is a case of sympathetic vibration of the first kind. By placing the piston at F the air will divide into nodes as in sympathetic vibration of the second kind. Now, if we remove the piston, and afterward the tube, it is evident that though we shall have no nodes and loops in this case, yet there is a similarity in the two cases. For the stationary waves may be considered as formed by the repeated reflection of progressive waves from the two ends of the tube.

Let us now descend from bodies of finite size to the molecules of a body and see whether they have any actions which we can explain by sympathetic vibrations. No man can say what is the shape or size of a molecule, or in what way it moves, but of this we are almost certain that either the molecules themselves, or some parts of them, have a periodic motion of some kind which we may suppose to be a

* For some excellent drawings of these see Ann. de Chim. et de Phys., 5me Serie, Tome i, p. 100

vibration. For when a gas is heated the waves of light which it gives out have a definite period of vibration, as is shown by the spectroscope. Hence, we should suppose that when those same waves strike upon another portion of the gas the particles of that gas would be set in motion by the waves. But to give the molecules motion, the motion of the waves must cease as we have seen it to do in the case of the two pendulums which exchange motion. Hence, we arrive at the law that those rays which a body gives out when heated will be absorbed by that body when they strike upon it. This, then, is the complete explanation of the dark lines in the solar spectrum; and we also deduce from this the theory of exchanges as it is called which has been developed in a most beautiful manner by Prof. Balfour Stewart.

We cannot suppose that the motion of the waves is accumulated in the molecules without limit; there must be something to take away their motion as it is given to them by the waves. We do not know what this is, but it may be that the molecules give out their motion once more in waves radiated in all directions, so that certain of the waves which compose the white light may be dispersed in all directions when passing through the gas, and thus the *direct* beam of light will lose most of those rays.

II. *Mathematical.*

The theory of this subject is simple, and at the same time very interesting, and, as I have not seen it treated elsewhere, I will spend a few moments in giving it.

Let the two bodies A and B be drawn to the points D and C, respectively, by forces which vary directly as the distances from those two points. And also let the two bodies be so connected, as, for instance, by a spring, that the mutual force between them will be proportional to the compression or stretching of the spring.

The two bodies, were they free from each other, would be capable of vibrating about the points D and C without influencing each other but as they are connected the case will be different.

Let n and n' be the masses of the two bodies.

Let x and y be the distances DA and CB respectively.

Let g and g' be the forces acting on the bodies when x and y are unity.

Let h be the force required to compress the spring by unity of length.

Then the equations to the motions of the two bodies are

$$\frac{d^2x}{dt^2} = -\frac{g}{n}x + \frac{h}{n}(y-x) \text{ and } \frac{d^2y}{dt^2} = -\frac{g'}{n'}y - \frac{h}{n'}(y-x),$$

$$\text{or, } \frac{d^2x}{dt^2} = -x\frac{h+g}{n} + y\frac{h}{n} \text{ and } \frac{d^2y}{dt^2} = x\frac{h}{n'} - y\frac{h+g'}{n'}$$

$$\text{Let } a = -\frac{h+g}{n};\ b = \frac{h}{n};\ a' = \frac{h}{n'};\ b' = -\frac{h+g'}{n'}.$$

The solution of these equations can be obtained by the method used by Boole (see Differential Equations, p. 310), and we shall then find:

$$x + m_1 y = C_1 e^{t\sqrt{a+a'm_1}} + C_2 e^{-t\sqrt{a+a'm_1}}$$

$$x + m_2 y = C_3 e^{t\sqrt{a+a'm_2}} + C_4 e^{-t\sqrt{a+a'm_2}}$$

where m_1 and m_2 are the two roots of the equation,

$$am + a'm^2 = b + b'm.$$

To determine the constants let the bodies at the time $t = 0$ be at rest, and so

$$\frac{dx}{dt} = 0 \text{ and } \frac{dy}{dt} = 0 \therefore C_1 = C_2 \text{ and } C_3 = C_4;$$

also when $t = 0$ let the body B be at C, and the body A be in the position $x = l$. Hence

$$C_1 = C_2 = \frac{l}{2} \text{ and } C_3 = C_4 = \frac{l}{2};$$

But from a well known theorem,

$$e^{pq\sqrt{-1}} + e^{-pq\sqrt{-1}} = 2\cos pq.$$

Hence we have finally,

$$(1)\quad y = \frac{l}{m_1 - m_2}\left\{\cos(t\sqrt{-a-a'm_1}) - \cos(t\sqrt{-a-a'm_2})\right\}$$

$$(2)\quad x = \frac{m_1 m_2 l}{m_2 - m_1}\left\{\frac{1}{m_1}\cos\left(t\sqrt{-a-a'm_1}\right) - \frac{1}{m_2}\cos\left(t\sqrt{-a-a'm_2}\right)\right\}$$

in which

$$m_1 = \frac{1}{2hn}\left\{(h+g')n - (h+g)n' + \sqrt{\{(h+g)n' - (h+g')n\}^2 + 4h^2nn'}\right\}$$

$$m_2 = \frac{1}{2hn}\left\{(h+g')n - (h+g)n' - \sqrt{\{(h+g)n' - (h+g')n\}^2 + 4h^2nn'}\right\}$$

When $h = 0$ there is no connection between the bodies, and the equations become

$$(3)\qquad y = 0 \text{ and } x = l\cos\left(t\sqrt{\frac{g}{n}}\right)$$

from which we see that B remains at rest and A oscillates indefinitely in the time $\pi\sqrt{\frac{n}{g}}$, the case of an ordinary pendulum. When, however, the bodies are attached together so that h has a value greater than zero, the case is different. In most cases of sympathetic vibration the bodies only influence each other slightly, so that the value of h is small; hence in the discussion we shall assume that h is small.

Equation (2) gives us the position of the first body at any instant t; and equation (1) gives us that of the second body.

In both cases the values of x and y depend upon two periodic terms, so that the motion of each body is a vibration compounded of two simple or harmonic vibrations; and, indeed, the motion of each may be represented by the same figure used to illustrate beats in the theory of sound.

Thus in Fig. 12 the horizontal lines represent the time t, the dotted curves the values of two terms in the equations, and the ordinates of the full curves the values of x and y. The figure represents the general case when the entire motion is not exchanged. We here observe that as t increases the motion of A is gradually given to B, so that the oscillations of A continually decrease in amplitude, while those of B increase until we get to a certain point, where the reverse takes place. In this case the first body never entirely comes to rest.

To see in what manner the bodies must be arranged in order that the motion of the second pendulum shall be the greatest possible, we proceed as follows:

The largest value which y can have as t increases is when

$$\cos(t\sqrt{-a-a'm_1}) = 1 \text{ and } \cos(t\sqrt{-a-a'm_2}) = -1,$$

and, therefore, $y_1 = \dfrac{2l}{m_2 - m_1}$ is the largest value of y.

This is a maximum when

$$(h+g)n' - (h+g')n = o'$$

$$\text{or, } \frac{g'}{n'} = \frac{g}{n} + h\frac{n'-n}{nn'}$$

When the bodies are only slightly connected, so that h is small, we have $\dfrac{g'}{n'} = \dfrac{g}{n}$ which, in eq. (3), shows that the time of vibration of the two bodies must be the same.

But, in general, $\dfrac{g'}{n'}$ will have a greater or less value than this, according as n' or n is the greater; so that the time of vibration of the heavier body must be less, when vibrating freely, than the other body.

When this adjustment is made the maximum value of y is $l\sqrt{\dfrac{n}{n'}}$ and at the same time x becomes o. The original amplitude of vibra- of the body A was $2l$, and after they had exchanged motions B has the amplitude $2l\sqrt{\dfrac{n}{n'}}$ so that the maximum amplitudes of two bodies exchanging motion in this way are inversely as the square roots of their masses.

In this case, when the bodies are adjusted for the best effect, we have

$$4\begin{cases} y = \frac{1}{2}l\sqrt{\dfrac{n}{n'}}\left[\cos\left\{t\sqrt{\dfrac{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}{n}}\right\} - \cos\left\{t\sqrt{\dfrac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{n}}\right\}\right] \\ y = \frac{1}{2}l\left[\cos\left\{t\sqrt{\dfrac{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}{n}}\right\} + \cos\left\{t\sqrt{\dfrac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{n}}\right\}\right] \end{cases}$$

These equations show that as t increases the vibrations of A become less and less, and those of B greater and greater, until a certain time, after which the reverse takes place and A regains its motion.

To find the time of this cycle we can proceed as follows: The two terms in the equations are periodic, and return to their primitive value after the times

$$2\pi\sqrt{\left\{\frac{n}{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}\right\}} \text{ and } 2\pi\sqrt{\left\{\frac{n}{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}\right\}}$$

Now, whenever they both arrive at their initial state together, the whole system will be in its initial state, and this will happen whenever s times the first is equal to p times the second, s and p being any positive whole numbers determined by the equation.

$$\frac{s^2}{p^2}=\left\{\frac{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}{g+h\left(1-\sqrt{\frac{n}{n'}}\right)}\right\}$$

This cannot always be exactly satisfied for small values of s and p unless there is a certain relation between the quantities in the right-hand member; but by giving large enough values it can always be satisfied. The time of the cycle will then be

$$2\pi s\sqrt{\left\{\frac{n}{g+h\left(1+\sqrt{\frac{n}{n'}}\right)}\right\}}$$

It is to be noted that several apparent exchanges of motion may take place before the complete cycle in which the system returns exactly to its initial state is gone through with.

If in eqs. (4) we make n very great and b very small the amplitude of A will remain almost undiminished and that of B will increase indefinitely. This is the case of a large, heavy body giving motion to a light one, which is only slightly connected with it.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA. NO. 1.—A NEW VERTICAL-LANTERN GALVANOMETER.*

By GEORGE F. BARKER, M.D., Professor of Physics.

Desiring to show to a large audience some delicate experiments in magneto-electric induction, in a recent lecture upon the Gramme machine, a new form of demonstration galvanometer was devised for the purpose, which has answered the object so well that it seems desirable to make some permanent record of its construction.

Various plans have already been proposed for making visible to an audience the oscillations of a galvanometer needle; but they all seem to have certain inherent objections which have prevented them from coming into general use. Perhaps the most common of these devices is that first used by Gauss in 1827, and adopted subsequently by Poggendorff and by Weber, which consists in attaching a mirror to the needle. By this means, a beam of light may be reflected to the zero point of a distant scale, and any deflection of the needle made clearly evident. The advantages of this method are:—1st, the motion of the needle may be indefinitely magnified by increasing the distance of the scale, and this without impairing the delicacy of the instrument; and 2d, the angular deflection of the needle is doubled by the reflection. These unquestioned advantages have led to the adoption of this method of reading in the most excellent galvanometers of Sir William Thomson. While therefore, for purposes of research, this method seems to leave very little to be desired, yet for purposes of lecture demonstration it has never come into very great favor; perhaps because the adjustments are somewhat tedious to make, and because, when made, the motion to the right or left of a spot of light upon a screen fails of its full significance to an average audience.

Another plan is that used by Mr. Tyndall in the lectures which he gave in this country. In principle, it is identical with that employed in the megascope; *i. e.*, a graduated circle over which the needle moves is strongly illuminated with the electric light, and then by means of a lens a magnified image of both circle and needle is formed

*A paper read before the Franklin Institute, June 16, 1875.

on the screen. The insufficient illumination given in this way, and the somewhat awkward arrangement of the apparatus required, have prevented its general adoption.

A much more satisfactory arrangement was described by Professor Mayer in 1872,* in which he appears to have made use, for the first time, of the excellent so-called vertical lantern in galvanometry. Upon the horizontal plane face of the condensing lens of this vertical lantern, Mayer places a delicately balanced magnetic needle, and on each side of the lens, separated by a distance equal to its diameter, is a flat spiral of square copper wire, the axis of these spirals passing through the point of suspension of the needle. A graduated circle is drawn or photographed on the glass beneath the needle, and the image of this, together with that of the needle itself, is projected on the screen, enlarged to any desirable extent. The defect of this apparatus, so excellent in many respects, seems to have been its want of delicacy; for in the same paper the use of a flat narrow coil, wound lengthwise about the needle, is recommended as better for thermal currents. Moreover, a year later, in 1873,† Mayer described another galvanometer improvement, entirely different in its character. In this latter instrument, the ordinary astatic galvanometer of Melloni was made use of, an inverted scale being drawn on the inside of the shade, in front of which traversed an index in the form of a small acute rhomb, attached to a balanced arm transverse to the axis of suspension of the needle, and moving with it. The scale and index were placed in front of the condensing lenses of an ordinary lantern, and their images were projected on the screen in the usual way by use of the objective. This instrument is essentially the same in principle as the mirror galvanometer; but it cannot be as sensitive as the latter, while it is open to the same objection which we have brought against this —the objection of unintelligibility. In the hands of so skillful an experimenter as Mayer, it seems, however, to have worked admirably.

It was a tacit conviction that none of the forms of apparatus now described would satisfactorily answer all the requirements of the lecture above referred to, that led to the devising of the galvanometer now to be described, which was constructed in February of the

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*Journal Franklin Institute, III. lxiii. 421, June, 1872. American Journal of Science, III. iii. 414, June 1872.

†American Journal of Science, III, v, 270, April, 1873.

present year. Like the first galvanometer of Mayer, the vertical lantern, as improved by Morton,* forms the basis of the apparatus. This vertical lantern, as constructed by George Wale & Co., at the Stevens Institute of Technology, as an attachment to the ordinary lantern, is shown in the annexed cut, Figure 1. Parallel rays of light, from the lantern in front of which it is placed, are received upon the mirror, which is inclined 45° to the horizon, and are thrown directly upward, upon the horizontal plano-convex lens just above. These rays, converged by the lens, enter the object glass, and are thrown on the screen by the smaller inclined mirror placed above it. The upper face of the lens forms thus a horizontal table, upon which water-tanks, etc., may be placed, and many beautiful experiments shown. To adapt this vertical lantern to the purposes of a galvanometer, a graduated circle, photographed on glass, is placed upon the horizontal condensing lens. Above this, a magnetic needle, of the shape of a very acute rhomb, is suspended by a filament of silk, which passes up through a loop, formed in a wire stretched close beneath the object glass, and thence down to the side pillar which supports this objective, where it is fastened by a bit of wax, to facilitate adjustment. The needle itself is fixed to an aluminum wire, which passes down through openings drilled in the scale glass, the horizontal lens, and the inclined mirror, and which carries a second needle near its lower end.† Surrounding this

(Fig. 1.)

*Jour. Frank. Inst., III, lxi, 300, May, 1871; Am. J. Sci., III, ii, 71, 153, July, Aug., 1871; Quar. J. Sci., Oct., 1871. In Duboscq's vertical attachment, which was advertised in his catalogue in 1870, the arrangement is similar, except that the beam received upon the mirror is a diverging one, and consequently the horizontal lens is of shorter focus. A total reflection prism, placed above the object glass, throws the light to the screen. The instrument gives a uniformly illuminated but not very bright field.

†After the new galvanometer was completed and had been in use for several weeks, I observed, in re-reading Mayer's first paper, a note stating that the idea had occurred to him of using an astatic combination consisting of two needles, one above the lens and the other below the inclined mirror—the two being connected by a stiff wire passing through holes in the condenser and the mirror. The plan of placing the coil round the lower needle does not seem to have suggested itself to him. Indeed, it does not appear that the arrangement he mentions was ever carried into practical effect.

lower needle is a circular coil of wire, having a cylindrical hollow core of an inch in diameter, in which the needle swings, and a smaller opening transverse to this, through which the suspension wire passes. In the apparatus already constructed (in which the upper needle is five centimeters long), the coil is composed of 100 feet of No. 14 copper wire, and has a resistance of 0·235 ohm. The accompanying cross section (Fig. 2,) of the vertical lantern galvanometer as at present arranged, drawn on a scale of 1-12, will serve to make the above description more clear. A is the needle, suspended directly above the scale-glass D, by a silk filament, passing through the loop B, close under the objective C. This needle is attached to the aluminum wire *a b*, which passes directly through the scale-glass D, the condensing lens E, and the inclined mirror F at H, and carries, near its lower end, the second needle I. This needle is shorter, (its length is 2·2 centimeters,) and heavier than the upper one, and moves in the core of the circular coil J, whose ends connect with the screw-cups at K. This coil rests on the base of the lantern, enclosed in a suitable frame. It is obvious that when the instrument is so placed that the coil is in the plane of the meridian, any current passing through this coil will act on the lower needle, and, since both needles are attached to the same wire, both will be simultaneously and equally deflected. Upon the screen is seen only the graduated circle and the upper needle; all the other parts of the apparatus are either out of the field or out of focus. Moreover, the hole in the lens is covered by the middle portion of the needle, and hence is not visible. The size of the image is, of course, determined by the distance of the galvanometer from the screen; in class experiments, a circle 8 feet in diameter is sufficient; though in the lecture above referred to, the circle was 16 feet across, and the needle was fourteen feet long, the field being brilliant.

(Fig. 2.)

The method of construction which has now been described, is evidently capable of producing a galvanometer for demonstration, whose delicacy may be determined at will, depending only on the kind of work to be done with it. In the first place, the needles may be made more or less perfectly astatic, and so freed more or less completely from the action of the earth's magnetism, and consequently more or less sensitive. Moreover, an astatic system seems to be preferable

to one in which damping magnets are used, since it is freer from influence by local causes; though, if desirable for a coarser class of experiments, the considerable distance which separates the needles in this instrument, allows the use of a damping magnet with either of them. In the galvanometer now in use, the upper needle is the stronger, and gives sufficient directive tendency to the system to bring the deflected needle back to zero quite promptly. In the experiments referred to below, the system made 25 oscillations per minute.

Secondly, the space beneath the mirror is sufficiently large to permit the use of a coil of any needed size. Since, therefore, the lower needle is entirely enclosed within the coil, the field of force within which it moves, may be made sensibly equal at all angles of deflection, as in the galvanometers of Sir Wm. Thomson. Hence the indications of the instrument may be made quantitative, at least within certain limits. The circular coil, too, has decided advantages over the flat coil, since the mass of wire being nearer to the needle, produces a more intense field. Were it desirable, a double coil, containing an astatic combination could be placed below the mirror, the upper needle, in that case, serving only as an index. The instrument above described has a coil three inches in diameter and one inch thick; the diameter of the core being one inch. Since its resistance is only about a quarter of an ohm it is intended for use with circuits of small resistance, such as thermo-currents and the like.

The results of a few experiments made with this new vertical-lantern galvanometer will illustrate the working of the instrument, and will demonstrate its delicacy. The apparatus used was not constructed especially for the purpose, but was a part of the University collection.

Induction Currents.—1. The galvanometer was connected with a coil of covered copper wire, No. 11 of the American wire gauge, about ten centimeters long and six in diameter, having a resistance of 0·323 ohm. A small bar magnet, 5 centimeters long and weighing six and a half grams, gave, when introduced into the coil, a deflection of 40°. On withdrawing the magnet the needle moved 40° in the opposite direction.

2. A small coil, 20 centimeters long and 3·5 in diameter, made of No. 16 wire and having a resistance of 0·371 ohm, through which the current of a Grenet battery, exposing 4 square inches of zinc surface, was passing, was introduced into the center of a large wire

coil, whose resistance was 0·295 ohm, connected with the galvanometer. The deflection produced was 20°. The same deflection was observed on making and breaking contact with the battery, the smaller coil remaining within the larger.

3. A coil of No. 14 copper wire, sixty centimeters in diameter, and containing about 40 turns, the resistance of which was 0·85 ohm, was connected with the galvanometer, and placed on the floor. Raising the south side six inches, caused a deflection of 4°. Placing the coil with its plane vertical, a movement of two centimeters to the right or left, caused a deflection of 3°, and of twenty centimeters, of 10°. A rotation of 90° gave a deflection of 12° and one of 180°, of 24°. These deflections were of course due to currents generated by the earth's magnetism.

4. *Thermo-currents.*—Two pieces of No. 22 wire fifteen centimeters long, were taken, the one of copper, and the other of iron wire, and united at one end by silver solder. On connecting the other ends to the galvanometer, the heat of the hand caused a deflection of the needle of 20°.

5. A thermo-pile of 15 pairs, each of bismuth and antimony, was connected to the instrument. The heat from the hand placed at five centimeters distance caused a deflection of 3°.

6. Two cubes of boiling water acted differentially on the pile. At the distance of five centimeters, the deflection was 20°; moving one to ten centimeters, the deflection was reduced to 5°.

7. *Voltaic current.*—A drop of water was placed on a zinc plate. While one of the connecting copper wires touched the zinc, the other was made to touch the water. The deflection was 16°.

The claim which is here made for the instrument however, is rather for the general principle of its construction, than for the advantages possessed by the individual galvanometer above described which was constructed at short notice, to meet an emergency. The comparatively small cost for which it may be fitted to the vertical lantern, the readiness with which it may be brought into use, the brilliantly illuminated circle of light which it gives upon the screen, with its graduated circle and needle, the great range of delicacy which may be given to the instrument by varying the coil and needles, so that all experimental requirements may be answered, and finally, the satisfactory character of its performance as a demonstration galvanometer, all combine to justify the record which is here made of it.

THE RAPID CORROSION OF IRON IN RAILWAY BRIDGES.

By Wm. Kent.

*A Paper presented, by request, to the U. S. Board appointed to examine Iron, Steel, etc.**

It has frequently been noticed that iron used in railway bridges, which is exposed to the smoke, steam and heated gases escaping from the passing locomotives, shows a greater tendency to corrode than iron in situations not so exposed. In some cases the iron beams and rods on the upper part of the bridge have been found to be rusted to such a depth that the safety of the bridge is endangered. It is, therefore, important to learn the causes of this rapid corrosion, in order to know what steps must be taken to prevent it.

A few weeks ago some pieces of iron rust, taken from a bridge on the Pennsylvania Railroad, were sent to the laboratory of the Stevens' Institute by Engineer J. M. Wilson, of the Pennsylvania R. R., and the writer made a qualitative chemical examination of them, to learn whether such examination would reveal any of the causes of the rusting.

The rust was in several pieces, or flat plates, some of which were as much as one-eighth of an inch in thickness. Some were quite friable, being easily broken by the fingers, while others required a light tap with a hammer to break them. All of the plates were covered on the outer side with a thick coating of a sooty nature, which was no doubt finely divided carbon deposited from the smoke of the locomotives. In other respects the rust was in no way distinguishable to the eye from iron rust formed in the atmosphere under ordinary circumstances. A portion of the rust was finely powdered, put into a flask, and distilled water, free from ammonia, added. The flask was tightly corked, and exposed to a gentle heat for two weeks. The water was then filtered off, and examined to find whether anything had gone into solution. It had a strongly bituminous odor, a thin oily film appeared upon the surface, and it was neutral to test paper. A careful qualitative analysis showed the presence, in the water solution, of iron, ammonia, sulphuric acid, and traces of sulphurous

* Sent to this Journal by Prof. Thurston, as a reprint from the *Iron Age*.

acid and chlorine. Nitric and nitrous acids were searched for but could not be found. A separate portion of the rust was tested for carbonic acid, and it was found in considerable quantity. The water solution was evaporated to dryness, and a small grayish residue was left.

The result of the analysis suggests at once the causes of the rapid oxidation of the iron. The presence of carbonic, sulphuric and sulphurous acids, no matter how small in quantity, is sufficient to promote rapid corrosion. The sources from which these substances are derived is evidently the escaping gases of the locomotive, which contain carbonic acid, carbonic oxide, moisture, and if there is sulphur in the coal, sulphurous and sulphuric acids. The chlorine and ammonia found may come either from the atmosphere, or from the water used in the locomotive. It would be interesting to know the action of each of the various gases above mentioned upon iron, to learn which of them has the greatest tendency to cause corrosion. The literature upon the subject is not extensive. One writer, however, Prof. F. Crace Calvert, has conclusively shown that carbonic acid is a most active agent, in presence of moisture, to promote corrosion. I refer to papers describing his experiments, published in the London *Chemical News*, January 28th and March 11th, 1870, and March 3d, 1871, and also to his experiments upon the action of sea water upon iron, published in the *Engineer*, August 25th, 1865, and *Engineering*, December 20th, 1867.

Among other interesting observations Prof. Calvert remarks that Claude Berdoulin first observed in 1683, that ammonia is formed when aërated water acts upon steel. In 1720, E. F. Geoffroy found that iron rust formed in the air contains moisture and ammonia. In his paper of March 3d, 1871, Prof. Calvert states that iron rust is generally supposed to be a hydrated sesquioxide of iron, containing a trace of ammonia, but two analyses made by him show that its constitution is much more complicated.

The following are the two analyses mentioned. The specimens were formed in the atmosphere, where they were carefully protected from any source of of contamination;

	Rust from Conway Bridge.	Llangollen.
Ferric Oxide, ...	93·094	92·900
Ferrous Oxide, ...	5·810	6·177

Carbonate of Iron, . . .	0·900	0·617
Silica, ...	0·196	0·121
Ammonia, ...	traces.	traces.
Carbonate of Lime, . . .		0·295

Prof. Calvert asks the question: "Is the oxidation of iron due to the direct action of the oxygen of the atmosphere, or to the decomposition of its aqueous vapor, or does the very small quantity of carbonic acid which it contains determine or intensify the oxidation of metallic iron?" To reply to it, he made a long series of experiments, by exposing perfectly cleaned blades of steel and iron to the action of different gases. After a period of four months, the blades showed the following results:

Dry oxygen—No oxidation.

Damp oxygen—In three experiments one blade only was slightly oxidized.

Dry carbonic acid—No oxidation.

Damp carbonic acid—Slight appearance of a white precipitate upon the iron, found to be carbonate of iron.

Dry carbonic acid and oxygen—No oxidation.

Damp carbonic acid and oxygen—Oxidation very rapid.

Dry and damp oxygen and ammonia—No oxidation.

These facts tend to show that carbonic acid, and not oxygen nor aqueous vapor, is the agent which determines the oxidation of iron in the atmosphere. Prof. Calvert also made experiments upon iron immersed in water containing carbonic acid, in sea water, and in very dilute solutions of hydrochloric, sulphuric and acetic acids. In one case a piece of cast iron placed in a dilute acetic acid solution for two years was reduced in weight from 15·324 grams to 3½ grams, and in specific gravity from 7·858 to 2·731, while the bulk and outward shape remained the same. The iron had gradually been dissolved or extracted from the mass, and in its place remained a carbon compound of less specific weight, and small cohesive force. The original cast iron contained 95 per cent. of iron and 3 per cent. of carbon, the new compound only 80 per cent. of iron and 11 per cent. of carbon. Iron immersed in water containing carbonic acid was also found to oxidize rapidly. Prof. Calvert states that the oxidation in this case was not due to the fixation of the oxygen dissolved in the water, but to oxygen liberated from the water by galvanic action.

The occurrence of hydrogen collected above the liquid in the bottles proved this sufficiently.

When distilled water was deprived of its gases by boiling, and a bright blade introduced, it became in the course of a few days here and there covered with rust. The spots where the oxidation had taken place were found to be impurities in the iron, which had induced a galvanic action, just as a mere trace of zinc placed on one end of the blade would establish a voltaic current.

With these researches of Prof. Calvert before us we have no difficulty in accounting for the rapid oxidation of iron in railway bridges. All the conditions necessary to promote corrosion are present. The carbonic acid and moisture escaping from the locomotives would themselves be sufficient; but when to this we add the sulphuric acid and chlorine, both of which were found in the analysis, we have, when they are dissolved in the moisture, an acid or a saline liquid capable of the most energetic action. Furthermore, the presence of the carbonaceous deposit has no doubt a tendency to assist the corrosion, both by its acting as a nucleus which retains the moisture and acid and condenses the gases within its pores, and by its inducing galvanic action, carbon being electro-negative to iron. The reason of the presence of ammonia in iron rust is stated by Bloxam, who says that it is formed from the nitrogen in the air during the process of rusting. It appears that the water is decomposed by the iron, and the liberated hydrogen enters at once into combination with the nitrogen held in solution by the water to form ammonia.

In connection with this subject, the writer has made an experiment to determine the action of sulphurous acid upon iron, as follows: Two one-half liter flasks were taken, and in one was placed about two ounces of clean and bright wrought iron turnings, and in the other two ounces of old rusty lath nails. Ten cubic centimeters of water was added to each, enough to merely wet the iron, and a current of sulphurous acid gas was then passed into each for a few minutes, and the flasks tightly corked and sealed. The gas had an immediate and energetic action in each case. The bright turnings at once became black, and then a white sandy-like deposit appeared in the bottom of the flask. On shaking this deposit around the side of the flask, it in a few minutes changed to a grayish color, and afterward a part of it became of the color of iron rust. The lath nails in the other flask at first lost their rusty appearance, and then the white deposit ap-

peared as in the first case. A third flask was then taken and ten cubic centimeters of water put in it and filled with sulphurous acid gas and corked, but no iron was put in it. All three flasks were kept corked for a week, and then opened. The third flask had a suffocating odor of sulphurous acid, and the water in the bottom contained both sulphurous and sulphuric acids. The other flasks were entirely free from any smell of sulphurous acid. The water was tested and found to contain protosulphate of iron. The precipitate around the sides of the flask was dissolved in hydrochloric acid and found to contain sulphuric acid and iron, both as ferrous and ferric oxides. The iron nails and turnings were weighed and found to have lost nearly 1 per cent. of their original weight. This experiment seems to show that sulphurous acid is rapidly changed into sulphuric acid in the presence of iron and moisture, and that the iron is thereby rapidly corroded. The sulphurous acid escaping from the locomotives must, therefore, be considered one of the most active agents of the corrosion of railway bridges.

STEVENS' INSTITUTE OF TECHNOLOGY,
Chemical Laboratory, May 19th, 1875.

MOLECULAR CHANGES IN METALS.*

By Prof. R. H. THURSTON.

In a series of articles contributed to the *Scientific American* during the past year, the writer gave an outline of the various phenomena affecting the strength of metals used in construction, and described some that were peculiar in character and but recently discovered, illustrating these facts by graphic representions of the changes of resistance with change of form, such as were obtained by the automatic action of the autographic testing machine of the Mechanical Laboratory of the Stevens' Institute of Technology. There are some phenomena which cannot be conveniently exhibited by strain diagrams;

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such are the molecular changes which occupy long periods of time. These phenomena, which consist in alterations of chemical constitution and molecular changes of structure, are not less important to the mechanic and the engineer than those already described. Requiring, usually, a considerable period of time for their production, they rarely attract attention, and it is only when the metal is finally inspected, after accidental or intentionally produced fracture, that these effects become observable.

The first change to be referred to is that gradual and imperceptible one which, occupying months and years, and under the ordinary influence of the weather, going on slowly but surely, results finally in important modification of the proportions of the chemical elements present, and in a consequent equally considerable change of the mechanical properties of the metal. The process of oxidation, or corrosion, is such a process, and is the most familiar one. Cast and wrought iron are both subject to it, the latter to, by far, the most serious extent. Cast iron is comparatively little affected by oxidation, even where exposed in wet situations or to alternate moisture and dryness. Wrought iron, under ordinary conditions of exposure, is said to be become rusted to the depth of a sixteenth of an inch in a quarter of a century. In exceptionally trying situations, it corrodes far more rapidly. Steam boilers are sometimes rusted through, about the water legs, at the rate of a sixteenth of an inch a year, and instances have been known of even more rapid work than this. Exposure, however, while producing oxidation, has another important effect: It sometimes produces an actual improvement in the character of the metal.

Every mechanic knows that old tools, which have been laid-aside or lost for a long time, seem to have acquired exceptional excellence of quality. Razors which have lost their keenness and their temper recover, like mankind, when given time and opportunity to recuperate. A spring regains its tension when allowed to rest. Farmers leave their scythes exposed to the weather, sometimes, from one season to another, and find their quality improved by it. Boiler makers frequently search old boilers carefully, when reopened for repairs after a long period of service, to find any tools that may have been left in them when last repaired; and if any are found, they are almost invariably of unusually fine quality. The writer, when a boy in the shop, frequently if denied the use of their tools by the workmen, looked about the scrap heaps and under the windows for tools purposely or carelessly dropped by the workmen; and when one was found badly

rusted by long exposure, it usually proved to be equal to the best of steel. One of the most striking illustrations of this improvement of the quality of wrought iron with time has recently come to the knowledge of the writer. The first wrought iron T-rails ever made were designed by Robert L. Stevens, about the year 1830, and were soon afterward laid down on the Camden and Amboy Railroad. These were Welsh rails, and, when put down, were considered, and actually were, brittle and poor iron. Many years later, these were replaced by new rails, but until quite recently some still remained on sidings. When a lot of unusually good iron was wanted, some of these rails were taken up and re-rolled into bar iron. The long period of exposure had so greatly changed the character of the metal that the effect was unmistakable. These facts are stated by gentlemen upon whom perfect reliance may be placed.

"But," it will be asked at once, "how can such changes occur without apparent cause, however long the time?" There are probably two methods of improvement, each due to an independent molecular action. In the case of the razor and the spring, which regain their tempers when permitted to rest, it seems probable that a molecular rearrangement of particles, disturbed by change of temperature in one case and by alternate flexing and relaxing in the other, goes on, much as the elevation of the elastic limit and the increase of resisting power, discovered by the writer and shown on the strain diagram, takes place under strain and set. The other cases may probably be due to a combination of this physical change with another purely chemical action, which is illustrated best in the manufacture of steel by the cementation process. In this process, iron, imbedded in charcoal and kept at red heat, gradually absorbs carbon and becomes steel. Here the element carbon enters the solid masses of iron, and diffuses itself with greater or less uniformity throughout their volume. There seems to exist a tendency to uniform distribution which is also seen in a thousand other chemical changes. Many chemical processes are accelerated, checked, and even reversed by simple changes of relative proportions of elements, which compel acceleration or reversal as the only means of securing this uniformity of distribution.

When, therefore, wrought iron containing injurious elements capable of oxidation, is exposed to the weather, the surface may be relieved by the combination of these elements with oxygen, and the surcharged interior, by this tendency to uniform diffusion, is relieved

by the flow of a portion to the surface, there to be oxidized and removed. This process of flow goes on until the metal, after lapse of years perhaps, becomes comparatively pure. Meantime the occurrence of jarring and tremor, such as rails are subjected to, may accelerate both this and the previously described change.

The effect of strains frequently applied, during long intervals of time, is quite different, however, where they are so great as to exceed the elastic range of the material. The effect of stresses which strain the metal beyond the elastic limit has already been referred to in the *Scientific American*. The case of the porter bar (of which a sketch was given, showing how, after a long period of severe usage, it finally broke suddenly, exhibiting the peculiar fracture characteristic of such a method of rupture) will probably be remembered by many readers. A still more marked case has recently come to the notice of the writer.

The great testing machine at the Washington Navy Yard has a capacity of about 300 tons, and has been in use 35 years. Quite recently, Commander Beardslee, whose valuable work has been alluded to in this paper, subjected it to a stress of 288,000 lbs., but it subsequently broke down under about 100 tons. The connecting bar which gave away had a diameter of five inches, and should have originally had a strength of about 1,000,000 lbs. Examining it after rupture, the fractured section was found to exhibit strata of varying thickness, each having a characteristic form of break. Some were quite granular in appearance, but the larger proportion were distinctly crystalline. Some of these crystals are large and well defined. The laminæ, or strata, preserve their characteristic peculiarities, whether of granulation or of crystallization, lying parallel to their axis and extending from the point of original fracture to a section about a foot distant, where the bar was broken a second time (and purposely) under a steam hammer. It thus differs from the granular structure which distinguishes the surfaces of a fracture suddenly produced by a single shock, and which is so generally confounded with real crystallization. This remarkable specimen has been contributed by the Navy Department to the cabinet of the Stevens' Institute of Technology.

The somewhat similar instance of the dropping-off of the end of an immense shaft at the Morgan Iron Works, some time since, while the opposite end was under the steam hammer, has been described in the *Scientific American*.

Were more conclusive evidence required of the occurrence of crystallization of iron, it has recently been given by an interesting incident at the Stevens' Institute of Technology. A student while annealing a number of steel hammer heads, left them exposed all night to the high temperature of the air furnace in the brass foundry. When finishing one of them, a careless blow broke it, and the fractured surface was found to possess a distinctly crystalline character.

[In the illustration, Figure 1 is a magnified representation of the surface of fracture. The two holes shown, penetrating the mass, are those drilled in the first operation, preparatory to fitting the handle. The facets of the crystals are seen to be remarkably perfect and well defined. Figure 2 represents the hammer on very nearly the natural scale.]

Fig. 1.

Fig. 2.

In this example, however, the faces were nearly all pentagonal, and were usually very perfectly formed. These illustrations are conclusive of the question whether iron may crystallize under the action of long continued and severe shocks, or of high temperature. When imperfect crystals are developed, it is easy to mistake them, but the formation of pentagonal dodecahedra, in large numbers and in perfectly accurate forms, may be considered unmistakable evidence of the fact that iron may crystallize in the cubic, or a modified, system. This may apparently take place either by very long-continued jarring of the particles beyond their elastic limits, or under the action of

high temperature, by either mechanical or physical tremor. But no evidence is given here that a single suddenly applied force, producing fracture, may cause such a systematic and complete rearrangement of molecules. The granular fracture produced by sudden breaking, and the crystalline structure produced as above during long periods of time, are, apparently, as distinct in nature as they are in their causes. The broken hammer head is so beautiful and perfect an illustration, and such instances are so rare, that it has been drawn and engraved by the accomplished gentlemen attached to the *Scientific American*, and is given in this article as the first illustration of the kind which has appeared in the literature of engineering.

Stevens' Institute of Technology, *Hoboken, N.J.*

On the Manufacture of Paper.—M. Aimé Girard, Professor at the Conservatoire des Arts et Metiers of Paris, has recently communicated to the French Academy, the results of his micrographic study of the tissues employed in paper making, which will be of interest to those engaged in this branch of manufacture. M. Girard has determined under the microscope the form, the dimensions and the special characteristics of each of the fibers employed in paper making at the present day. He has also made photo-micrographs of these fibers. As a result of these examinations, he has been led to formulate the precise conditions which a fiber of good quality for making paper, should fulfill.

Very much has been said, for example, of the value of length in fibers designed for use in the manufacture of paper; but this concern about long fiber has no foundation in the facts of the case. The crude, and in fact the finished pulp, is composed of fragments measuring either from 0·3 to 0·5 of a millimeter, in short pulp; or from one to one and a half millimeters, (one twenty-fifth to one sixteenth of an inch) in the long pulp; it is rare to find this length exceeded. Now there is no vegetable fiber known, the length of which is not at least equal to the latter figures. Hence there is no vegetable fiber too short for the manufacture of paper.

There is however a condition which is of extreme importance in this relation. It is that the fiber should be fine and elongated; that, in a word, the ratio of its length to its diameter should be considerable. This ratio, for a fiber, after cutting and pulping in the paper machine, should be as 50 to 1 as a minimum; moreover, the fiber

should be elastic; and finally, it should be flexible and capable of being bent and twisted with facility. It is under these conditions alone that the felting of the fiber can give solidity to the sheet. On the contrary, the tenacity of the fiber, which is sometimes considered so essential, has in fact only a secondary importance; since when a sheet of paper is torn, the fibers themselves are almost never ruptured, but escape entire from the felted mass by sliding over their neighbors. In short, the value of a vegetable fiber designed for the manufacture of paper does not depend, as is so often asserted, upon its length, nor even upon its tenacity, but before all these, upon its elasticity, upon the fineness of its diameter, and upon the facility with which it may be bent on itself.

Having fixed these principles, M. Girard classifies provisionally, while awaiting the results of further research, the principle substances employed in the manufacture of paper into five different groups. These classes comprise: 1st, Round fibers having well marked nodes. 2d, Smooth fibers or fibers with indistinct nodes. 3d, Fibro-cellular substances. 4th, Flat fibers; and 5th, Imperfect materials.

1. *Round fibers with well defined nodes.*—Such fibers are those of hemp and flax. The textile fiber of hemp is different from its paper-making fiber. The former is composed of finer fibers cemented together, and forming large bundles even one-tenth of a millimeter in diameter. In the pulp of hemp scrap, the fibers are detached from the bundles and are separately visible, appearing in the form of nearly cylindrical rods, intersected by frequent transverse nodes which give to them the appearance of bamboos. The diameter of these fibers varies from one-fiftieth to one-eightieth of a millimeter. These fibers are fissile, splitting easily into a multitude of fibrillæ, which clasping each other firmly, give to the paper made from canvas, a very great solidity. Flax presents in its fibers, great similarity with hemp. But its fissility is less pronounced and the diameter of the fibrillæ is less, varying from one-eightieth to one-hundreth of a millimeter.

2. *Round smooth fibers, nodes indistinct.*—In this class belong esparto grass, jute, phormium fiber, palmetto, hop, and sugar cane. England consumes annually 250,000 tons of esparto grass. Its fiber is fine and slender, measuring only one-hundredth of a millimeter in diameter, and being five millimeters in length. These fibers felt together very well. Of jute, England consumes 200,000 tons a year. Under this name are included various East Indian vegetable products. The fibers, while closely analogous for the different varieties, resemble

in general those of hemp and flax. The fibers of *phormium tenax* are very similar to those of esparto, and felt well together. The palmetto, when treated chemically, gives round fibers, having nodes, but much finer than those of hemp or flax. The hop has recently begun to attract the serious attention of manufacturers, and for some time, it has been employed for paper making. An important advance has lately been made in this direction, by improvements made in the construction of machines for decorticating the plant. From the bark thus detached, two sorts of fibers, mixed together, are extracted. One of these, and this the most abundant, measures about one-hundreth of a millimeter; the other measures about one-thirtieth of a millimeter. The latter seem to possess a certain fissility, analogous to flax and hemp. Sugar cane is at present treated in the Antilles by a chemical process. From the bagasse, fibers are extracted in this way, which are round and regular, and which may be readily bent and twisted.

3. *Fibro-cellular substances.*—Of these the most common, is the pulp obtained from rye or wheat-straw, by submitting it to the action of caustic soda under pressure, at a temperature of 120° to 130° C. This pulp is a mixture of round fibers with indistinct nodes, which bend easily, with larger grains or cellules of various forms. It is to the presence of these grains, incapable of being felted or bent, that M. Girard attributes the defects recognized in all straw paper.

4. *Flat fibers.*—These fibers comprise those of cotton, of wood extracted by chemical processes, of the agave, of the paper mulberry and of the bamboo. The flat fibers of cotton are easily bent. The polygonal fibers of pine and fir wood, split up into flat fibers, in the middle of which the dotted tissue appears. The production of these fibers is to-day a very wide spread mechanical industry. The fiber of the agave is flat and easily twisted. The mulberry gives a flat and very long fiber. The trial of the bamboo for the benefit of the paper maker seems on the eve of assuming a considerable industrial importance. The fiber, analogous to that of the paper mulberry, is flat and may be bent with facility.

5. *Imperfect materials.*—In concluding this list of the vegetable substances employed in the manufacture of paper, it is necessary to mention the pulp obtained by the mechanical comminution of wood. This pulp is not made up of fibrous materials, properly so-called. It is composed of bundles of fibers, still adhering together, sometimes in so great a number as to constitute true sticks. The element thus mechanically produced from the wood is a rigid fragment, incapable of being bent, or of giving a solid felt. The introduction of such material into paper can produce only very unsatisfactory results.